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THE NORTH ATLANTIC FINE AND MICROSTRUCTURE CRUISE KNORR 52 AND --ETC(U)

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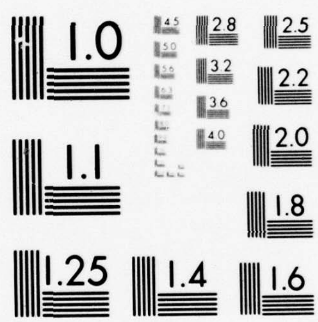
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In the fall of 1975 a three-ship, multi-investigator, ONR-sponsored study was made of the distribution of fine- and microstructure in the Northwest Atlantic (the North Atlantic Fine- and Microstructure Cruise). A variety of sophisticated, highly sensitive instrumentation was used to observe the small scale variability of temperature, salinity and velocity in the ocean. This report summarizes the cruise objectives, describes the instrumentation and gives information concerning the observations and data quality.

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THE NORTH ATLANTIC FINE AND MICROSTRUCTURE CRUISE *Knorr* 52 and *Eastward* 75-12

by

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WOODS HOLE OCEANOGRAPHIC INSTITUTION
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February 1977

TECHNICAL REPORT

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Approved for Distribution Dean F. Bumpus

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Department of Physical Oceanography

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ABSTRACT

In the fall of 1975 a three ship, multi-investigator, ONR-sponsored study was made of the distribution of fine- and micro-structure in the Northwest Atlantic (the North Atlantic Fine- and Microstructure Cruise). A variety of sophisticated, highly sensitive instrumentation was used to observe the small scale variability of temperature, salinity and velocity in the ocean. This report summarizes the cruise objectives, describes the instrumentation and gives information concerning the observations and data quality.

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I. INTRODUCTION

A. The North Atlantic Fine and Microstructure Cruise

A large number of investigators, using a variety of newly developed instrumentation, are studying variations of temperature, salinity, velocity and other quantities over centimeter and smaller spatial scales. In order to further these researches into the generation, transport and dissipation of small-scale property gradients in the sea and to intercompare measurements, a multi-investigator cruise was performed under the encouragement and financial support of the Office of Naval Research. The program has been called the North Atlantic Fine and Microstructure Cruise. This report summarizes the scientific goals and field program.

B. Background

Microstructure is defined as the variation of water properties over vertical distances of 0.2 meters and less. It is the signature of processes which are responsible for the ultimate destruction and dissipation of variations of water properties. Kinetic energy and distinct water types produced by global scale sources undergo continual stirring by a cascade of ever-smaller eddies until property gradients on centimeter and smaller length scales result over which molecular diffusion is a dominant process. The dissipation of property gradients is virtually complete at the microstructure length scales. No significant variations of temperature, salinity, or velocity exist on scales smaller than the respective diffusive cut-off scale.

Microstructure arises because property gradients are continually being produced in the ocean. Large-scale intrusions of differing water masses, such as the Mediterranean water into the eastern North Atlantic Ocean, constantly produce strong gradients of water types. Moreover, the tides and winds impart kinetic energy into the sea which is dissipated. Several mechanisms have been suggested which stir the ocean, thereby sharpening property gradients, leading to microscale mixing in the deep ocean.

One mechanism arises when the vertical shear of the velocity profile exceeds a critical value. Low frequency currents and higher frequency internal waves can combine at any depth and time to produce supercritical shears. Enhanced mixing results as the zone becomes unstable and experiences turbulent overturning. Internal waves with sufficient amplitude can also interact to produce local regions of negative static stability followed by convective mixing. Another stirring mechanism arises because different properties diffuse at different rates. When the diffusing properties are salt and heat convective motion, commonly called salt fingers, can result in active mixing. These processes result in a vertical flux of water properties through dissipation of property gradients.

An understanding of the spatial and temporal distribution of microstructure is of vital importance in oceanography. Observational programs are needed to determine the temporal and spatial distributions of vertical fluxes and levels of dissipation. These data will help to clarify how the kinetic energy from the tides and winds is dissipated, how intrusive features of differing water types are mixed, how moored instruments are influenced by microstructure, and how levels of acoustic backscattering and diffraction can be estimated.

C. Previous Measurements

During the past several years instrument systems capable of resolving temperature, conductivity, and velocity fluctuations to scales ranging from a few meters to centimeters have been developed. Individual investigators working with the data from their instruments are attempting to describe the small scale variability of the ocean and to relate it to larger scale features. Operating singly the new techniques have yielded much important information. The electromagnetic velocity profiler (EMVP, Sanford, 1975) has found regions of intense vertical shear, with much of the energy at near-inertial frequencies and propagating downward. Larger scale velocity fluctuations have been related to a baroclinic mode structure and show variations in regions with rough and smooth bottom topography. The self-imaging optical profiler (SCIMP, Williams, 1974b) has found direct evidence of salt fingers in some of the regions where the larger scale structures

had suggested double diffusivity processes. The centimeter-scale temperature microstructure measurements have shown that the temperature fluctuations in the ocean tend to be dissipated in patches of only a few meters in vertical extent and a few hundred meters in the horizontal. The most intense temperature dissipation regions yet found have been on the upper and lower boundaries of 2 to 30 meter thick intrusions of one water mass into another. This microstructure activity appears to result from both double diffusivity and shear effects. However, the measured levels of turbulent activity are not large enough to support the 1 cm^2/sec value predicted by thermocline theories.

The indications of low mixing rates have come, principally from Eastern Pacific Ocean observations. Other data suggest that the Atlantic has more microstructure activity. Yet, few actual microstructure measurements have been made in the Atlantic.

There are only meager data available to define the source mechanisms operating, the overall rate of dissipation, and the geographical distribution. Recent advances in the measurement of centimeter-scale velocity fluctuations offer the promise of relating energy dissipation to temperature microstructure.

II. METRIC AND SCIENTIFIC GOALS OF THE NORTH ATLANTIC FINE AND MICROSTRUCTURE CRUISE

A. Cruise Goals

The ultimate goal of the cruise is to understand the mechanisms by which the forcing of the ocean by air-sea interactions and tides is dissipated by the centimeter-scale fluctuations--often at locations in the interior of the fluid. In order to obtain energy and heat budgets, including the vertical fluxes, combined measurements covering a wide range of space and time scales will be required. As a modest first step some of the new instruments were brought together in an attempt to do simultaneous measurements of previously unrelated scales of observation. Of the assembled measurement instruments, some made similar measurements and some had no counterpart. The combined data are being used to examine instrument performance and to define property gradients over a broad range of vertical scales.

The immediate goals of the cruise were to:

1. Explore regional differences in fine and microstructure activity using measurements at a variety of sites;

2. Exploit simultaneous measurements by instruments of differing resolution;

3. Intercompare similar measurements in order to better define instrument performance;

4. Define requirements for future measurements and instrumentation.

B. Participants

The observational program was carried out by nine investigators operating from three research vessels. Listed below and in Table I are the investigators and a brief description of their instruments. A fuller description of the instruments is included in Chapter III and Appendix.

Investigator	Research Vessel	Instrument	Description
Tom Sanford Chief Scientist (W.H.O.I.)	R/V Knorr	Electromagnetic velocity profiler "EMVP"	Measures the larger-scale shear (scales of 10 m and greater)
Mike Gregg (University of Washington)	R/V Knorr	Free-fall microstructure recorder "MSR"	Measures variability in temperature and conductivity on the cm scale over specified depth intervals. Complements the CTD information
Ann Gargett (Pat Bay Ocean Institute, Victoria, B.C.)	R/V Knorr	Tom Osborn's (University of B.C.) high-resolution velocity shear recorder "CAMEL"	Measures shear on scales from 50 to 1 cm. Complements the E-M profiler and measures the smallest important scales in the velocity-gradient variance
Sandy Williams (W.H.O.I.)	R/V Knorr	"SCIMP"	Looks at small-scale vertical structures - dropped simultaneously with other microstructure profilers
Tom Rossby Dave Evans (University of Rhode Island)	R/V Knorr	Free-fall shear meter "YVETTE"	Measures velocity, shear, temperature, conductivity, and pressure
John Stratford (Marine Sciences Lab, Menai Bridge, U.K.)	R/V Knorr	John Simpson's (Marine Science Lab) "PROTAS"	Shear profiler
CTD Group (W.H.O.I.)	R/V Knorr	Brown CTD	
Nelson Hogg Chief Scientist (W.H.O.I.)	R/V Eastward		CTD, GEK, XBT, and float work
Eli Katz Chief Scientist (W.H.O.I.)	R/V Chain	towed CTD	Data help define the horizontal structure of gradient regions

Table I. Summary of Instruments and Deployments in the North Atlantic Fine- and Microstructure Cruise.

Investigators	Instrument	Variables Measured	Scales	Number of Deployments
Knorr				
Sanford	Electromagnetic Velocity Profiler "EMVP"	T, V, C, P T_z	5000 - 10 m 50 - 1 cm	82
Williams	Self-Imaging Optical Profiler "SCIMP"	T, C, $\nabla^2 n$, P V_z	600 m - cm 1 m - cm	19
Gregg	Microstructure Recorder "MSR"	T, C, T_z, C_z, P	150 m - cm	34
Osborn and Gargett	Microstructure Recorder "CAMEL"	T, C, T_z, C_z, P V_z	500 m - cm 50 - 1 cm	31
Rossby	Shear Meter "YVETTE"	T, C, P, V_z	1000 m - 10 cm 3 m - 10 cm	12
Simpson	Shear Meter "PROTAS"	T, C, P V_z, T_z	500 m - 10 cm 6 m - 12 cm	45
[W.H.O.I. CTD]	W.H.O.I. Brown CTD	C, T, P	5000 m - 10 cm	79
Eastward				
Hogg	CTD	C, T, D	5000 m - 10 cm	96
	Swallow floats	V	10 - 1 km	5
	XBT	T	800 - 10 m	144
	GEK	V	1000 - 1 km	5
Chain				
Katz	Horizontal tows of STD and current meter	S, T, D, V	10 km - 10 m	2 tows
Other Activities				
Wunsch	Microstructure Array--moored	T, V, T_z, V_z	10 day - sec	1 Setting
Buoy Group	3 moorings Apr 1975 - Jan 1976	T, V, P	9 mo - 15 min	13 V&T Instruments 3 T&P Instruments

Key:

C, conductivity
CTD, conductivity-temperature-depth sensor
D, depth
n, refractive index
P, pressure
$(\ )_z$, $\partial(\ )/\partial z$
S, salinity
STD, salinity-temperature-depth sensor
T, temperautre
V, velocity
Z, depth

C. Open Ocean, Gulf Stream, and Continental Slope Surveys

Observations from the Pacific and elsewhere suggest that the general level of turbulence in the open ocean is so small that associated eddy diffusion coefficients approach the molecular values. They are considerably smaller than values needed to support diffusive thermocline ocean models. Regions of effective stirring may be confined to the ocean boundaries or to strong boundary currents. However, other observations in the central Atlantic Ocean with the EMVP (Sanford, 1975) show large shears in the horizontal velocity which are associated with near-inertial frequency waves. These shears are so large, in fact, that the Richardson number calculated from them approaches unity. It may be that what little microstructure there is observed in the open ocean is associated with these regions of large shear. STD-scale temperature and salinity profiles do suggest that the Atlantic is much more active than the Pacific but high resolution profiles have not yet been made in the Atlantic.

We, therefore, devoted about half of the R/V Knorr time to surveys of microstructure activity from the region of the Continental Slope to Bermuda.

The open ocean work, conducted at 35° N, 66° 30' W, consisted of five days of repeated profiles. These measurements were made in a region of low horizontal variability in order to facilitate the intercomparison of measurements.

In addition to an instrument intercomparison specific objectives of the open ocean work were:

1. To obtain measurements of the rate of dissipation of velocity, ε, and temperature fluctuations, χ, in a representative western Atlantic site. Measurements of χ have been taken in the eastern Pacific.

2. To relate the microstructure measurements (scales of 0.2 meter and less) to the fine-scale (100 meters to 1 meter) velocity structure. Of prime interest is the dissipative effect of the high shear regions. The larger scale velocity measurements are also required for an

attempt to determine the shear stress from the microscale velocity measurements.

3. To relate the optical shadowgraph images to microscale temperature and velocity measurements.

An operational goal of this work, that all instruments be operating simultaneously during this period, was fulfilled. Never before have simultaneous studies been made of microstructure with both high resolution velocity, temperature, and salinity profiles as well as the lower resolution CTD and electromagnetic velocity profiles.

D. The Bermuda Surveys

Mid-ocean islands provide obvious locations for the interaction of the ocean with its boundaries and may, in fact, act as "stirring rods" for the central ocean. Wunsch (1972) and Hogg (1972) describe isolated patches of intense stirring near Bermuda as evidenced by the existence of large, well-mixed regions on temperature versus depth profiles taken on three separate STD surveys (see Fig. 1). On each occasion the region appeared to be located to the left of the island, looking downstream. A theoretical model presented by Hogg (1972) concerning the quasi-geostrophic adjustment of a steady flow to the island also indicated that this was the region of least dynamic stability or minimum Richardson number:

$$Ri = \frac{-\frac{g}{\rho}\frac{\partial \rho}{\partial z}}{\left(\frac{\partial u}{\partial z}\right)^2}$$

(g being the acceleration due to gravity and $\partial\rho/\partial z$ and $\partial u/\partial z$ the underlying density and velocity gradients). In support of this hypothesis, available data indicated that the Richardson number was reduced from a number of order 10^2 away from Bermuda to unity in the anomalous region.

With the successful development of the free-fall electro-magnetic velocity profiler and microstructure profilers it is now possible to correlate more conclusively the occurrence of intense microstructure

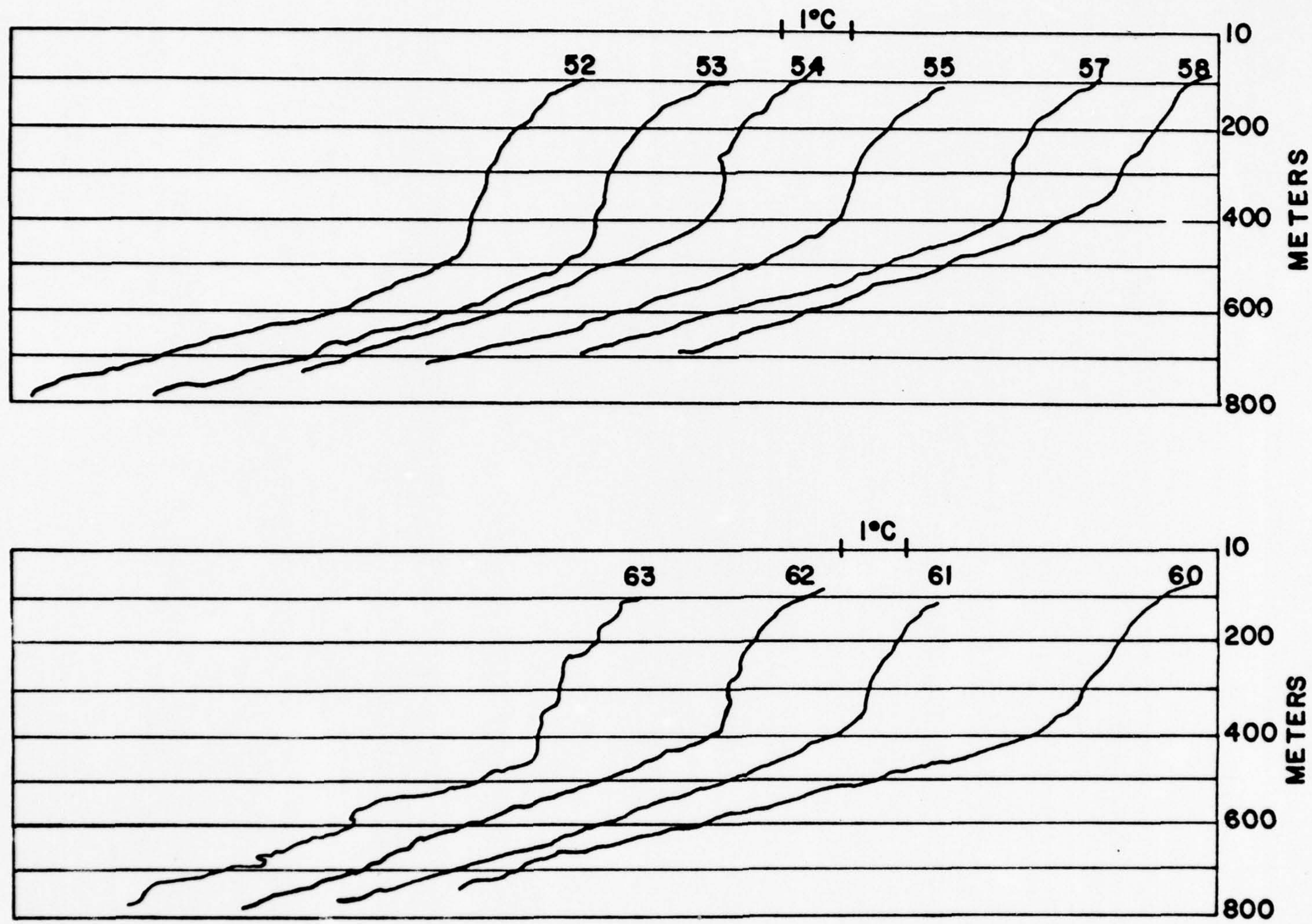

Fig. 1. Two STD sections radiating out from Bermuda with island to the left

near the island with low values of the Richardson number and to estimate the importance of this island interaction in mixing water types and dissipating energy.

The near Bermuda phase of the work involved three research vessels: the R/V Knorr, the R/V Chain of the Woods Hole Oceanographic Institution and the R/V Eastward of the Duke University Cooperative Oceanographic Program. The Eastward arrived first at Bermuda on October 17, 1975 and used the CTD system, neutrally-buoyant floats, XBTs, and a new GEK for eleven days surveying the large-scale flow field out to a distance of 75 km from the island center. The survey consisted of 4 concentric circuits around the island. During this period the Chain made two tows of a CTD fish to define the horizontal extent of active regions. On October 24 the Knorr, with the CTD, velocity profiling, and microstructure teams, arrived to begin the intensive microstructure investigation. After a port stop in Bermuda (October 28-30) the final six days of Eastward time were spent tracking neutrally buoyant Swallow floats, and redoing one of the earlier circuits of the island to assess long-term changes. As another and more accurate monitor of temporal changes in the low-frequency flow field, three current meter moorings have been deployed by the Moored Array Program of W.H.O.I.

The CTD stations, CTD tows and current meter locations are shown in Fig. 2.

The specific objectives of the Bermuda surveys were to:

1. Map low-frequency flow pattern around Bermuda.

2. Map the three-dimensional location of the active fine-structure region in relation of the mean flow around the island. This was done with the towed CTD on the CHAIN as well as with a net of vertical profiling stations.

3. Look at quasi-steady changes in the potential energy field associated with the active region.

4. Examine the microstructure, in space and time, in the "nearly isothermal" step-like regions.

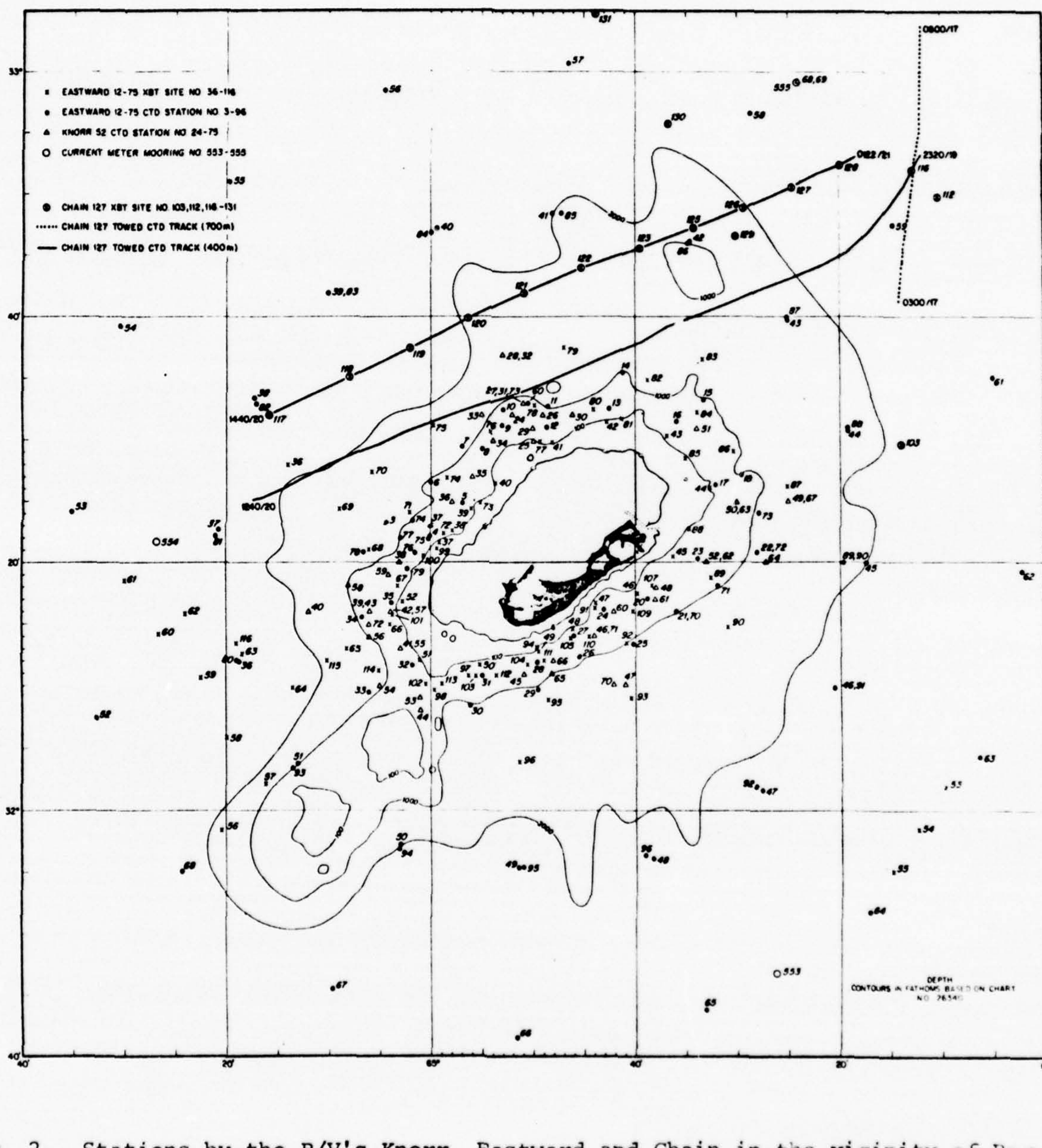

Fig. 2. Stations by the R/V's Knorr, Eastward and Chain in the vicinity of Bermuda

5. Measure the dissipation rates, χ and ε, and compare the dissipation rates in the lee of the island with those measured at other locations. Are such islands "stirring rods of the ocean?"

III. FIELD PROGRAM

A. Discussion of Methods

Vertical profiles, horizontal tows, and moored measurements were combined to generate our picture of fine and microstructure activity. The individuals and teams responsible for each instrument have approached these measurements from different directions and the instruments measure different quantities or different scales and the analyses are not identical. In spite of these differences, much of the development has been convergent. Temperature measurements are made on all instruments and conductivity and relative velocity are measured on most. A description of the instruments and methods of each investigator is presented in this section. Additional information is presented in the Appendix.

1. The Electro-Magnetic Velocity Profiler, EMVP

The EMVP used by Sanford (Sanford, Drever and Dunlap, 1974) is a free-fall probe which measures electric field, temperature, conductivity, and pressure. The electric field is a measure of the relative velocity. The principle of this measurement is that the horizontal motion of the seawater in the vertical component of the geomagnetic field produces a horizontal electric field. The shunting resistance of the vertical water column establishes a single electric field, independent of depth, which is proportional to the conductivity weighted mean velocity. The free falling probe responds to local variations from the mean velocity, and an electric field is similarly produced by its own motion in the vertical geomagnetic field. The difference between these two fields is the sensible quantity, which is thus proportional to the horizontal velocity of the probe relative to the mean seawater velocity.

Silver-silver chloride electrodes in an electrode block are connected by salt bridges to the skin of the probe where the potential is sensed. The probe rotates as it falls and the phase of the signal from a pair of electrodes is compared to the phase of the signal from a compass coil to determine the azimuth of the current. Two pairs of electric field

sensors at right angles are used to obtain complete coverage. The vertical resolution is 10 meters and the accuracy appears to be 0.5 cm/sec in relative horizontal velocity. Electric field, compass, pressure, temperature, and conductivity are digitized to 12-bit precision and stored on magnetic tape cassettes.

Profiles of velocity are the normal output of the computer analysis. Shear profiles, temperature profiles, and Brunt-Väisälä frequency profiles can also be made and a Richardson number can be estimated.

2. Rossby's Acoustic Shear Profiler

This profiler is a free-fall CTD microprofiler with an acoustic velocimeter at the lower end. The velocimeter sends two acoustic pulses horizontally through the water, pulse 1 goes from transducer A to transducer B and pulse 2 goes from B to A. The difference in transit time is proportional to the component of velocity along this path. Two horizontal velocity components are measured with four transducers. A compass provides azimuth information.

The probe is more than 4 meters long and sinks at 20 cm/sec. Thus the horizontal velocity of the center of displacement closely matches the average of the horizontal velocity over the length of the probe. The relative velocity of the water at the lower end is measured by the acoustic velocimeter. This is then the difference in velocity from the average four meters above. The limit of vertical resolution is 10 cm and the sensitivity is 1 mm/sec. Unlike the EMVP measurement which is not degraded at low wavenumber since it is referred to the mean of the entire water column, Rossby's measurement is bandpassed by its reference to a sliding average. Ten meters is the large-scale limit of the measurement.

The CTD is an internally-recording, slow-digitizing version of the cable-lowered CTD. Temperature, conductivity, and pressure are digitized to 16 bits. Then, the two axes of velocity digitized to 12 bits, and the compass, digitized to 8 bits are recorded on magnetic tape cassette. Profiles of velocity, temperature, salinity, and Richardson number are generated from these tapes by computer.

3. Osborn's Shear Profiler

The probe developed by Osborn (1974) measures velocity shear, temperature, conductivity, pressure, and vertical gradients of temperature and conductivity. The vehicle consists of a pressure cylinder about 5 m long. The upper endcap of the housing holds a radio transmitter, flashing light, and acoustic pinger (for retrieval), together with the expendable wire cartridge. Mounting fixtures for the velocity probe and ancillary sensors are attached to the lower end cap. Small vanes attached to the upper end of the housing induce a rotation of approximately one minute period. At a predetermined depth a pressure activated mechanism releases the two lead ballasting weights and the instrument returns to the surface. The shear sensor employs a tiny axisymmetric, side force sensor which is exposed to an oncoming flow directed along the probe axis. In the present application the onset flow is provided by dropping the probe vertically down into the ocean with a uniform drop velocity $\overline{U}$. Alternatively the device can be towed or propelled through the medium to be sampled. The probe responds in much the same manner as a phonograph pick-up which detects the "waviness" in a record groove. It measures the waviness in an oncoming flow. If a single spectral component of horizontal velocity structure is represented by a sinusoidal shear wave of wavelength λ, a modulating side force will be impressed on the sensor as it penetrates through the transverse velocity field. The side force results from a distribution of positive and negative pressures which, for an axisymmetric body-of-revolution, is distributed over the first 2-3 diameters of length. The force is detected by making the probe nose-piece of a moderately flexible substance (such as epoxy or another moldable material) in which is embedded one or more piezoceramic bimorph beams of the type commonly employed in phonograph cartridges. By incorporating two bimorph elements with an orthogonal orientation, the two components of horizontal shear velocity v and w are simultaneously converted into time varying voltages.

Osborn sends the data to the surface on a fine wire filament which "spins-off" of a cartridge much like a fishing reel, as the body descends. The cartridges, known as Expendable Wire Links, are manufactured by Sippican Corporation. All data signals, except for rotation rate, are telemetered up the insulated conductor on standard I.R.I.G.-FM channels. The sea water is used as a return line. The rotation rate is telemetered as a periodic variation in the offset voltage of the wire.

4. Simpson's Shear Profiler, PROTAS

PROTAS (Simpson, 1972) is a free-fall probe which uses a pivoted neutrally buoyant vane system to measure velocity shear. Simultaneous measurements of temperature, conductivity, pressure, and orientation are also made. Data is recorded twice every second and stored in digital form on a magnetic tape-cassette.

The body of the probe consists of an HE 30 WP alloy tube of wall thickness 6.35 mm and diameter 18 cm. The present unit can operate to a depth of 500 m with a safety factor of 2. A slightly thicker walled tube, capable of reaching a depth of 2000 m, is planned for later versions of PROTAS.

The ends of the tube are streamlined by fibre glass fairings which also house the recovery aids. At the lower end of the tube there is a 10 kHz acoustic beacon, while in the upper fairing, a discharge tube flashing light is provided to assist in locating the probe at night.

When the probe reaches its terminal depth, ballast is released by one of the two tension pin pressure releases. The second weight is detached by a corrodable link, which also acts as a back-up time release in the event of a failure in the hydrostatic system.

To achieve the necessary degree of static stability, the internal payload (electronics, batteries, recorder) is carried in the lower half of the tube. The righting moment is further enhanced by the positioning of the ballast weight and the lead collar which is used for ballast adjustments.

Movement of the shear detecting vane is sensed by an electrode on the end of the vane which picks up two alternating voltages provided by pairs of fixed electrodes. The pickup electrode is, in effect, the wiper of the two resistive potentiometers formed by pairs of fixed electrodes. The two signals are at different frequencies and may, therefore, be separated by tuned amplifiers and converted by phase sensitive detection to voltages, which for small displacements, represent the rectangular coordinates of the tip of the vane.

At a fall speed of 30 cm/sec and with a vane length of 30 cm, a cross flow of 1 mm/sec produces a vane movement of 1 mm, a displacement readily detectable by the pick-up circuitry.

Temperature gradient is measured by differentiating the output from a single thermistor. In free-fall, where the vertical velocity W is accurately known, the time rate of change of temperature may be interpreted as a spatial gradient. To improve the signal to noise ratio, the conventional active differentiator circuit is preceded by a low noise amplifier. The thermistor is a Fenwal GB32 which has a time constant of $\tau \sim 150$ msec and hence a vertical resolution ~ 5 cm for $W = 30$ cm/sec. A faster response thermistor GC32 ($\tau \sim 80$ msec when mounted in pressure proof unit) will allow a slight improvement on this figure.

Temperature and depth are measured by conventional thermistor and strain gauge techniques. Data from all five channels are recorded on a small photographic galvanometer recorder at chart speeds of 0.6 or 3 mm/sec.

5. Gregg's Microstructure Recorder, MSR

The instrument used by Gregg (Gregg and Cox, 1971) is an upgraded version of the one operated at Scripps for the past seven years. It records data internally, using a sea data recorder and 15-bit analog to digital converter. For maximum dynamic range, temperature and electrical conductivity are recorded at 50 Hz from the high-pass, high-gain circuits and at 5 Hz from the low gain, but nearly full bandwidth channels. Additional high-pass data is recorded at 50 Hz from a thermistor mounted on

the tip of one of the rotating wing blades. Other information sampled at 5 Hz includes pressure, temperature from a stable Wein bridge oscillator, rotation and engineering parameters. The temperature sensors are 0.020-inch diameter glass rod thermistors with a resistance at 25° C of 750 kΩ. The conductivity probe is in principle similar to that described by Gregg and Cox (1971).

The pressure tube for the electronics is mounted in a pivoted platform welded to the ship's rail. The platform is swung outboard and vertical for launch and recovery. The instrument is transferred to and from the water by a line from an articulated crane. Prior to launch an iron ballast weight and protective cover for the probes are locked into the end cap. The protective ring is released by contact with sea water, for surface drops, or at a preset pressure. This also frees the wing blades so the vehicle begins rotating as it takes data during the subsequent slow descent, $\sim 0.1 \text{ m} \cdot \text{s}^{-1}$. After a recording interval of 38 or 58 minutes, depending upon the thickness of tape used, the recording cycle is stopped and the ballast released. A radio and flashing light are mounted on the package to aid recovery.

The data is transcribed using the sea data reader and an interface to the Ocean Physics Group CHI-2130. During the cruise only analog plots were available.

6. SCIMP

SCIMP (Williams, 1974) is a freely sinking platform with an internally recording CTD, acoustic velocimeter, and optical imaging system. The platform can vary its weight upon acoustic command to maintain a descent rate of 10 cm/sec. The velocimeter sensors extend 1 meter below the center of buoyancy of the rest of the package and are sensitive to 1 mm/sec velocity differences. The expected resolution of shear is 3 mm/sec over a vertical separation of 1 meter. The CTD profile consists of digitizations at 200 ms intervals to 16 bits in pressure, temperature, and conductivity. The temperature sensor is a Rosemount platinum resistance thermometer with a time constant of 400 ms at 10 cm/sec corrected

with a thermistor, the differentiated output of which is added to restore the high frequency response. Conductivity is sensed with a four electrode cell 3 mm in diameter and 8 mm long. Its flushing length is estimated to be 3 cm at 10 cm/sec. The resolution of the strain gauge pressure transducer is 5 cm of depth.

The optical imaging system forms a shadowgraph from a collimated beam of light 5 cm in diameter which has traversed 160 cm of water in a horizontal path. The beam is folded by a retro-reflector 80 cm from the pressure windows. Index of refraction anomalies in the water, caused by sub-centimeter scale temperature and salinity structure, refract the collimated light. A telescope in the image-forming portion of the instrument provides an effective path of 20 meters for the weakly refracting microstructure to focus the light into a shadowgraph pattern. This is photographed on movie film at a rate of 1 frame per second.

The instrument weighs 180 kg in air but is trimmed to have negative bucyancy of approximately 1 kg when sinking at 10 cm/sec. Sinking rate and depth are acoustically telemetered to the surface and acoustic commands to jettison alcohol or sodium dichromate brine are sent back to the instrument to control the rate. Telemetry is time encoded pulses every 2 seconds on 5 kHz. Acoustic commands are sent on 10 kHz using the AMF channel 7 and three commands-up, down, return to surface. It sinks to a maximum depth of 2000 meters then releases a weight to return to the surface at 30 cm/sec. It is tracked acoustically as it rises. On the surface it is located by direction finding on an OAR radio beacon (Channel A, 26.995 mHz) and by looking for its flag or flashing OAR light.

Normal weight release is triggered by a measurement of some preset depth but the weight will be released by exceeding the preset time or by acoustic command from the surface. A shear pin in the release device is selected to fail at some pressure greater than the programmed maximum depth in case of electrical failure.

The instrument is launched by crane and recovered by attaching a line to it with a latching hook on a pole, drawing it close to the ship,

putting a crane hook on it, and lifting it aboard with the crane. Recovery can be done day or night to sea state four.

The tape is read into the computer where salinity, density, and potential temperature are computed and plotted with depth, temperature, and north and east components of shear. The film is developed and viewed to determine what structures at the subcentimeter scale are associated with the finestructure features on the profile.

B. Cruise Report and Observation Log for the R/V *Knorr*

The *Knorr* departed Woods Hole on 15 October 1975 following a rhumb line toward Bermuda. After a brief stop near Site D for instrument tests, we proceeded to 35° N, 66° 30' W for a five and one-half day time series of profiles to study the temporal and vertical variability of fine and microstructure at a mid-ocean site. A total of 82 profiles were obtained, most of which were simultaneous, multi-instrument deployments.

On the 23rd we proceeded to Bermuda to study the spatial distribution of currents and microstructure. The aim of this work was to assess the importance of island-induced turbulence and variability. We rendezvoused with the *Eastward* on the 25th and, using their recent results, began a series of profile stations distributed around the island. This work continued until the 28th when we entered the port of St. George's, Bermuda, to plan the survey for the remaining time, and to take aboard the Microstructure Array (MSA) of Wunsch and the Draper Lab of M.I.T. Tom Rossby and Dave Evans of U.R.I. joined the ship with the instrument named YVETTE.

In the afternoon of 30 October we left port and proceeded to the western end of the island. During the night we conducted a fathometer survey to select a suitable site for deploying the Draper Lab MSA. Unfortunately, we were unable to deploy the MSA due to high winds (30 knots) and rough seas. After a very considerable effort we decided to return to port and off-load the MSA since there was some external damage to it and a concern that it may have more serious, unapparent damage.

By evening of the 31st we were again at sea profiling in spite of rather rough sea conditions. The new arrival to the instrument stable, YVETTE, was deployed for the first time that evening and subsequently failed to return as expected. An acoustic search was maintained for several hours which succeeded in fixing its drifting position three times. The next day was devoted to further profile work, but in the evening we steamed along the expected path of YVETTE and found her. As we were recovering this instrument, we received a request from the Navy to supply assistance to the U.S.S. Bartlett which had been disabled due to rope and chain around her propeller. We returned to Bermuda to take on a team of divers and proceeded to the Bartlett. Working at night in rough seas, these divers removed the entanglement. By afternoon of 3 November we had returned the divers to Bermuda and began our work.

Our profile studies around Bermuda continued until the afternoon of 6 November when we headed toward our previous site at 35° N, 66° 30' W. Here we profiled for about one day and then headed toward the Gulf Stream, making an XBT section while underway.

In the Gulf Stream we obtained profiles at several sites across the Stream in a period of one day. The sites were chosen to provide regions of differing shear.

The Knorr and all of the profiling instruments returned to Woods Hole in the morning of 11 November, 1975.

The positions of all of the Knorr observations are shown in Fig. 3, and those around Bermuda are presented in Fig. 4. Further information about the Knorr observations are given in Table II. Meteorological observations are presented in Table III.

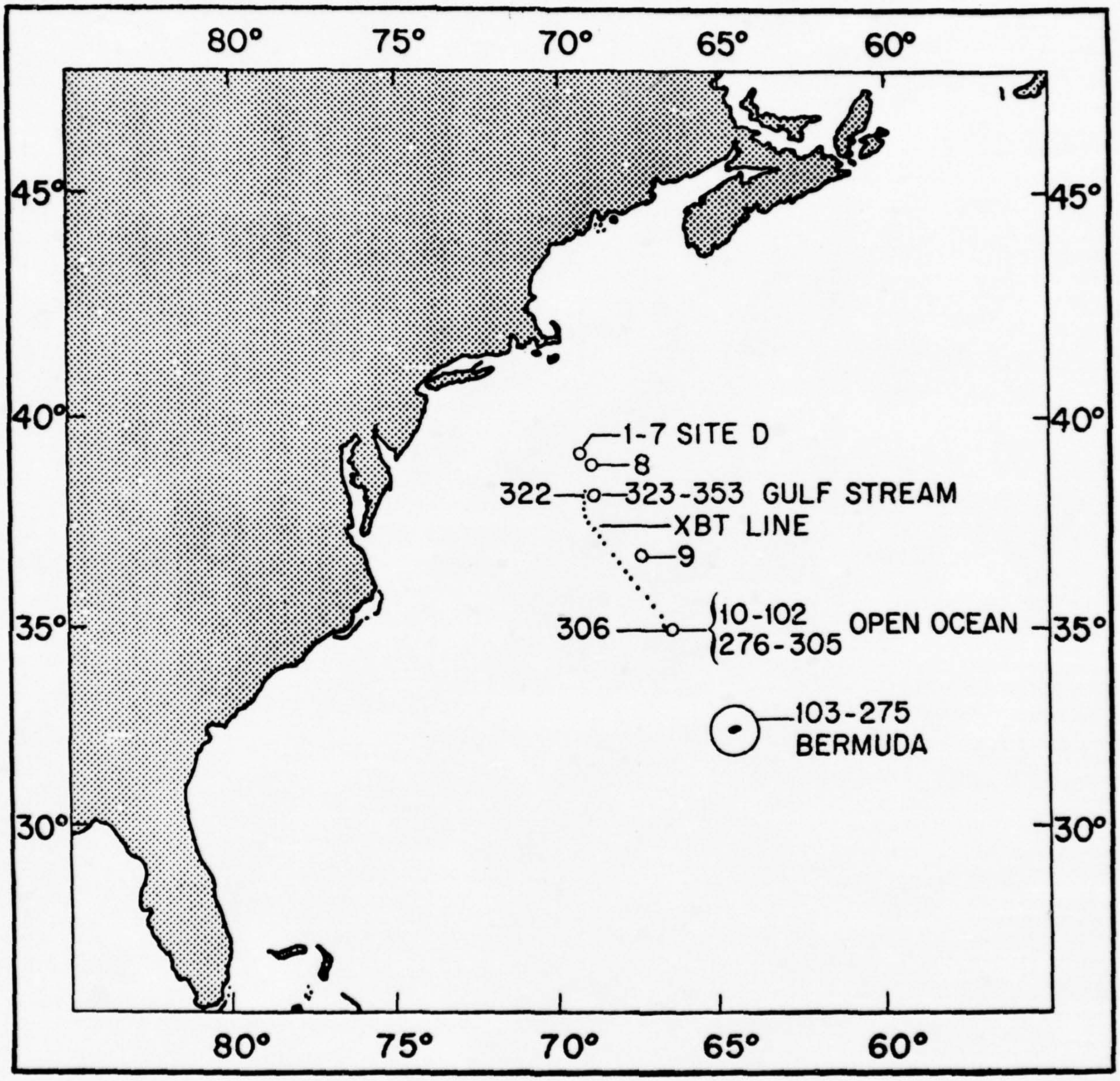

Fig. 3. R/V <u>Knorr</u> 52. Observations Nos. 1-373, 15 Oct. - 11 Nov., 1975

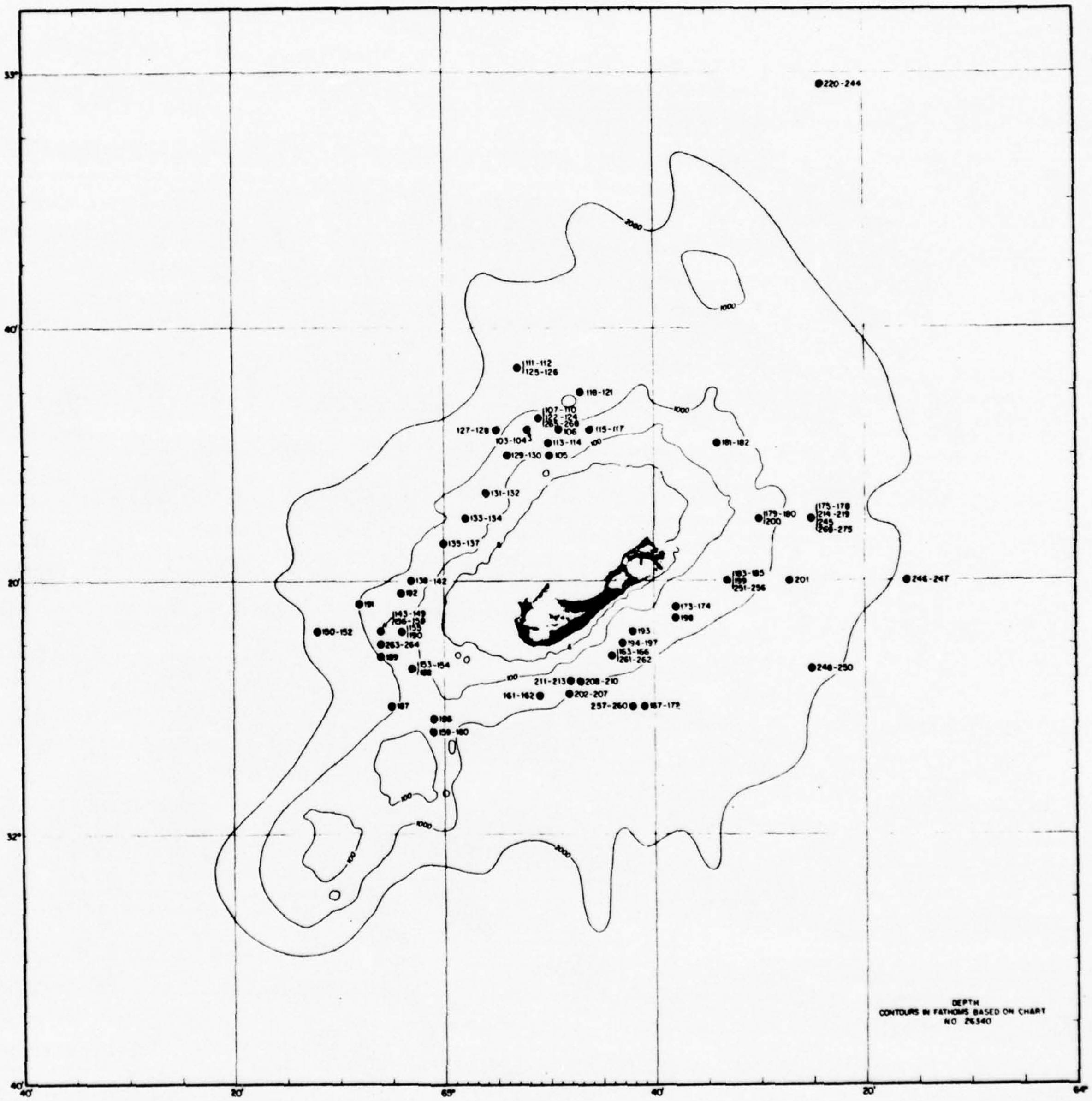

Fig. 4. R/V Knorr 52. Observation Nos. 103-275 near Bermuda, 25 Oct. - 5 Nov., 1975

Table II

KNORR 52 SCIENTIFIC OBSERVATIONS

Table Key:

C, conductivity

CTD, conductivity-temperature depth sensor

D, depth

n, refractive index

P, pressure

S, salinity

STD, salinity-temperature-depth sensor

T, temperature

V, velocity

Z, depth

$( )_z = \partial( )/\partial z$

Instrument Abbreviations	Instrument	Investigators	Variables Measured	Scales
EMVP	Electromagnetic Velocity Profiler	Sanford	T,V,C,P	5000 - 10 m
SCIMP	Self-Imaging Optical Profiler	Williams	$T,C,\nabla^2 n,P$ V_z	600 m - cm 1 m - cm
MSR	Microstructure Recorder	Gregg	$T,C,T_z,$ C_z,P	150 m - cm
CAMEL	Microstructure Recorder	Osborn & Gargett	T,C,T_z,C_z,P V_z	500 m - cm 5 m - cm
YVETTE	Shear Meter	Rossby	T,C,P, V_z	1000 m - 10 cm 3 m - 10 cm
PROTAS	Shear Meter	Simpson	T,C,P, V_z,T_z	500 m - 10 cm 6 m - 12 cm
CTD	WHOI/Brown CTD	[WHOI CTD]	C,T,P	5000 - 1 m
XBT	T-7 Expendable Bathythermograph	WHOI	T	5 - 750 m
XBT-FS	Experimental Fine Structure XBT	WHOI/Sippican	T	1 - 200 m

Table II. KNORR 52 SCIENTIFIC OBSERVATIONS

Obs. #	Instrum. #	Date (GMT)	Time (GMT)	Approx. Launch Position Lat. (N)	Long. (W)	Comments
1	PROTAS 1	10/16	1515	39° 03'	69° 08'	
2	PROTAS 2	10/16	1707	39° 04'	69° 07'	
3	PROTAS 3	10/16	1727	39° 04'	69° 08'	20-400 m
4	XBT 1		1800	39° 05'	69° 08'	
5	MSR 7		1815	39° 05'	69° 08'	No data
6	CAMEL 1		2030	39° 07'	68° 08'	No data
7	SCIMP 1		2127	39° 07'	69° 07'	0-50-590 m
8	CTD 1	10/17	0220	38° 52'	68° 57'	0-2493 dbar
9	EMVP 248	10/17	1752	36° 45'	67° 28'	0-5066 dbar
10	CTD 2	10/18	0805	35° 03'	66° 30'	0-1603 dbar
11	CTD 3	10/18	0920	35° 03'	66° 27'	0-1601 dbar
12	CTD 4	10/18		35° 00'	66° 28'	0-3405 dbar
13	CTD 5	10/18	1330	35° 00'	66° 32'	0-3717 dbar
14	EMVP 249		1326	35° 00'	66° 31'	0-5142 dbar
15	MSR 8	10/18	1654	35° 00'	66° 30'	No data
16	PROTAS 4		1655	35° 00'	66° 30'	20-350 m
17	CTD 6		1708	35° 00'	66° 30'	0-1555 dbar
18	SCIMP 2	10/18	2005	35° 00'	66° 30'	0-500-1190 m
19	EMVP 250		2029	35° 00'	66° 30'	No data
20	CAMEL 2		2029	35° 00'	66° 30'	No data
21	CTD 7	10/19	0109	35° 00'	66° 30'	0-3729 dbar
22	PROTAS 5	10/19	1413	34° 59'	66° 30'	20-530 m
23	EMVP 251		1425	34° 59'	66° 30'	0-5137 dbar
24	CTD 8		1429	34° 59'	66° 31'	0-961 dbar
25	SCIMP 3	10/19	1919	35° 00'	66° 30'	0-120 m
26	PROTAS 6		1923	35° 00'	66° 30'	20-420 m
27	MSR 9		1949	35° 00'	66° 30'	No data
28	EMVP 252		2003	34° 59'	66° 29'	0-5126 dbar
29	CAMEL 3		1957	34° 59'	66° 29'	No data
30	XBT-FS 1	10/19	2305	35° 01'	66° 31'	
31	CTD 9		2334	35° 00'	66° 30'	0-3691 dbar
32	EMVP 253	10/20	0156	35° 00'	66° 30'	0-5136 dbar
33	PROTAS 7	10/20	0600	35° 00'	66° 30'	20-800 m
34	EMVP 254	10/20	0704	35° 00'	66° 30'	0-5139 dbar
35	CTD 10		0754	35° 00'	66° 30'	0-3637 dbar
36	EMVP 255	10/20	1124	35° 00'	66° 30'	0-5142 dbar
37	CTD 11		1205	35° 00'	66° 30'	0-4055 dbar
38	CAMEL 4	10/20	1455	35° 02'	66° 31'	No data
39	XBT-FS 2		1450	35° 02'	66° 31'	
40	XBT-FS 3		1514	35° 02'	66° 31'	
41	XBT-FS4	10/20	1702	35° 00'	66° 30'	
42	PROTAS 2		1701	35° 00'	66° 30'	20-800 m
43	MSR 10		1703	35° 00'	66° 30'	50-300 m, hi-freq. no good

Table II - KNORR 52 SCIENTIFIC OBSERVATIONS

Obs. #	Instrum. #	Date (GMT)	Time (GMT)	Approx. Launch Position Lat. (N)	Long. (W)	Comments
44	XBT-FS 5	10/20	1726	35° 00'	66° 30'	
45	EMVP 256		1727	35° 00'	66° 30'	0-5128 dbar
46	CTD 12		1730	35° 00'	66° 30'	0-1043 dbar
47	CTD 13	10/20	2105	35° 00'	66° 30'	0-1597 dbar
48	XBT-FS 6	10/20	2220	35° 00'	66° 30'	
49	EMVP 257		2230	35° 00'	66° 30'	0-5136 dbar
50	CTD 14		2258	35° 00'	66° 30'	0-4009 dbar
51	EMVP 258	10/21	0320	35° 00'	66° 31'	0-5158 dbar
52	PROTAS 9		0314	35° 00'	66° 31'	20-1000 m
53	XBT-FS 7		0315	35° 00'	66° 31'	
54	CTD 15		0325	35° 00'	66° 32'	0-1507 dbar
55	EMVP 259	10/21	0846	35° 00'	66° 31'	0-5161 dbar
56	CTD 16		0911	35° 00'	66° 30'	0-2841 dbar
57	PROTAS 10	10/21	1334	35° 00'	66° 30'	20-1000 m
58	EMVP 260	10/21	1401	35° 00'	66° 31'	0-5160 dbar
59	EMVP 261		1401	35° 00'	66° 31'	No data
60	CAMEL 5		1405	35° 00'	66° 31'	0-500 m
61	EMVP 262	10/21	1845	35° 00'	66° 30'	0-5141 dbar
62	CTD 17		1845	35° 00'	66° 30'	0-4001 dbar
63	EMVP 263	10/21	2322	35° 00'	66° 30'	0-5139 dbar,up missing above 4013 dbar
64	EMVP 264		2322	35° 00'	66° 30'	0-5140 dbar
65	XBT-FS 8		2315	35° 00'	66° 30'	
66	PROTAS 11		2324	35° 00'	66° 30'	20-1000 m
67	CAMEL 6		2324	35° 00'	66° 30'	No data
68	XBT-FS 9		2330	35° 00'	66° 30'	
69	CTD 18		2335	35° 00'	66° 31'	0-1501 dbar
70	EMVP 265	10/22	0440	35° 00'	66° 30'	0-5139 dbar
71	CTD 19	10/22	0550	35° 00'	66° 30'	0-1997 dbar
72	EMVP 266	10/22	0950	35° 00'	66° 30'	0-5136 dbar
73	PROTAS 12		0946	35° 00'	66° 30'	20-1000 m
74	CAMEL 7		0947	35° 00'	66° 30'	0-725 m, T?
75	XBT-FS 10		1030	35° 00'	66° 30'	
76	EMVP 267	10/22	1429	35° 00'	66° 30'	0-5133 dbar
77	XBT-FS 11		1437	35° 00'	66° 30'	
78	CTD 20		1445	35° 00'	66° 30'	0-5039 dbar
79	XBT-FS 12		1451	35° 00'	66° 30'	
80	CTD 21	10/22	1830	35° 00'	66° 30'	0-1605 dbar
81	SCIMP 4	10/22	2005	35° 01'	66° 31'	No data
82	XBT-FS 12		2015	35° 01'	66° 31'	
83	PROTAS 13		2006	35° 01'	66° 31'	20-1000 m
84	CAMEL 8	10/22	2208	35° 00'	66° 30'	0-750 m, no T
85	EMVP 268		2212	35° 00'	66° 30'	0-5130 dbar
86	MSR 11	10/22	2251	35° 01'	66° 30'	No data
87	EMVP 269	10/23	0224	35° 02'	66° 33'	0-5149 dbar
88	EMVP 270		0224	35° 00'	66° 30'	0-5127 dbar

Table II - KNORR 52 SCIENTIFIC OBSERVATIONS

Obs. #	Instrum. #	Date (GMT)	Time (GMT)	Approx. Launch Position Lat. (N)	Long. (W)	Comments
89	CTD 22	10/23	0300	35° 00'	66° 31'	0-1519 dbar
90	MSR 12	10/23	0413	35° 01'	66° 31'	No data
91	PROTAS 14	10/23	0810	35° 00'	66° 30'	20-1000 m
92	EMVP 271		0813	35° 00'	66° 30'	0-5137 dbar
93	CTD 23		0829	35° 00'	66° 31'	0-1999 dbar
94	EMVP 272	10/23	1250	35° 02'	66° 33'	0-5145 dbar
95	EMVP 273		1250	35° 00'	66° 30'	0-5134 dbar
96	PROTAS 15	10/23	1307	35° 01'	66° 30'	20-1000 m
97	MSR 13	10/23	1609	35° 01'	66° 31'	900-1125 m,hi-freq. no good
98	EMVP 274	10/23	1749	35° 00'	66° 30'	0-5141 dbar
99	SCIMP 5		1744	35° 00'	66° 30'	No data
100	PROTAS 16		1750	35° 00'	66° 30'	20-1000 m
101	CAMEL 9		1750	35° 00'	66° 30'	0-485 m
102	MSR 14	10/23	2228	35° 01'	66° 31'	No data
103	PROTAS 17	10/24	1746	32° 32'	64° 52'	20-600 m
104	CTD 24		1755	32° 32'	64° 52'	0-1105 dbar
105	CTD 25	10/24	2000	32° 30'	64° 50'	Yo-yo Station - 5 cycles to about 500 dbar
106	CTD 26	10/25	0000	32° 33'	64° 49'	0-1945 dbar
107	MSR 15	10/25	0308	32° 33'	64° 51'	No data
108	SCIMP 6		0310	32° 33'	64° 51'	0-100-600 m
109	EMVP 275	10/25	0541	32° 33'	64° 51'	0-1839 dbar
110	CTD 27		0547	32° 33'	64° 51'	0-1605 dbar
111	EMVP 276	10/25	0845	32° 37'	64° 53'	0-3489 dbar
112	CTD 28	10/25	0855	32° 37'	64° 53'	0-2491 dbar
113	EMVP 277	10/25	1254	32° 31'	64° 50'	0-1166 dbar
114	CTD 29		1303	32° 31'	64° 50'	0-1005 dbar
115	EMVP 278	10/25	1502	32° 32'	64° 46'	0-1161 dbar
116	CAMEL 10		1515	32° 32'	64° 46'	0-580 m
117	CTD 30	10/25	1610	32° 32'	64° 47'	0-1105 dbar
118	EMVP 279	10/25	1842	32° 35'	64° 47'	0-2245 dbar
119	MSR 16		1818	32° 35'	64° 47'	50-275 m,hi-freq. no good
120	PROTAS 18		1820	32° 35'	64° 47'	20-∿500 m
121	CAMEL 11		1822	32° 35'	64° 47'	0-425 m
122	EMVP 280	10/25	2059	32° 33'	64° 51'	0-1719 dbar
123	MSR 17		2105	32° 33'	64° 51'	No data
124	CTD 31		2110	32° 33'	64° 50'	0-800 dbar
125	EMVP 281	10/25	2345	32° 37'	64° 53'	0-3413 dbar
126	CTD 32		2357	32° 36'	64° 52'	0-3113 dbar
127	EMVP 282	10/26	0312	32° 32'	64° 55'	0-1934 dbar
128	CTD 33		0324	32° 32'	64° 55'	0-1939 dbar
129	EMVP 283	10/26	0616	32° 30'	64° 54'	0-1180 dbar
130	CTD 34		0630	32° 30'	64° 54'	0-1061 dbar

Table II - KNORR 52 SCIENTIFIC OBSERVATIONS

Obs. #	Instrum. #	Date (GMT)	Time (GMT)	Approx. Launch Position Lat. (N)	Long. (W)	Comments
131	EMVP 284	10/26	0819	32° 27'	64° 55'	0-1175 dbar
132	CTD 35		0825	32° 27'	64° 55'	0-789 dbar
133	EMVP 285	10/26	1033	32° 25'	64° 58'	0-1170 dbar
134	CTD 36		1040	32° 26'	64° 58'	0-987 dbar
135	EMVP 286	10/26	1259	32° 23'	65° 00'	0-1352 dbar
135	MSR 18		1251	32° 23'	65° 00'	No data
137	CTD 37		1306	32° 23'	65° 00'	0-1303 dbar
138	SCIMP 7	10/26	1515	32° 20'	65° 03'	0-120-150-300 m
139	EMVP 287		1540	32° 19'	65° 03'	0-1339 dbar
140	PROTAS 19		1532	32° 19'	65° 03'	40-600 m
141	CAMEL 12		1550	32° 19'	65° 03'	0-740 m
142	CTD 38	10/26	1800	32° 20'	65° 02'	0-1015 dbar
143	CTD 39	10/26	1935	32° 16'	65° 06'	0-1539 dbar
144	SCIMP 8	10/26	2025	32° 16'	65° 06'	0-500-800 m
145	XBT-FS 14		2036	32° 16'	65° 06'	
146	EMVP 288		2043	32° 16'	65° 06'	0-1635 dbar
147	PROTAS 20		2041	32° 16'	65° 06'	40-800 m
148	MSR 19		2043	32° 16'	65° 06'	300-550 m
149	CAMEL 13		2045	32° 16'	65° 06'	0-725 m
150	EMVP 289	10/27	0141	32° 16'	65° 12'	0-3640 dbar
151	MSR 20		0138	32° 16'	65° 12'	350-600 m
152	CTD 40		0148	32° 16'	65° 12'	0-2215 dbar
153	EMVP 290	10/27	0457	32° 13'	65° 03'	0-971 dbar
154	CTD 41		0512	32° 13'	65° 03'	0-801 dbar
155	CTD 42	10/27	0630	32° 16'	65° 04'	0-751 dbar
156	PROTAS 21	10/27	0719	32° 16'	65° 06'	40-1000 m
157	EMVP 291		0740	32° 16'	65° 06'	0-1715 dbar
158	CTD 43		0740	32° 16'	65° 06'	0-1513 dbar
159	EMVP 292	10/27	1025	32° 09'	65° 01'	0-835 dbar
160	CTD 44		1025	32° 09'	65° 01'	0-647 dbar
161	EMVP 293	10/27	1235	32° 11'	64° 51'	0-1192 dbar
162	CTD 45		1237	32° 11'	64° 51'	0-1155 dbar
163	CTD 46	10/27	1445	32° 14'	64° 44'	0-1325 dbar
164	EMVP 294		1526	32° 14'	64° 44'	0-1455 dbar
165	CAMEL 14		1515	32° 14'	64° 44'	0-795 m
166	XBT-FS 15			32° 14'	64° 44'	
167	SCIMP 9	10/27	1739	32° 10'	64° 41'	0-500-530-900 m
168	CTD 47		1745	32° 10'	64° 41'	0-2501 dbar
169	XBT-FS 16	10/27	1901	32° 10'	64° 42'	
170	EMVP 295		1855	32° 10'	64° 41'	0-2646 dbar
171	PROTAS 22		1902	32° 10'	64° 42'	40-800 m
172	CAMEL 15		1902	32° 10'	64° 42'	0-740 m
173	EMVP 296	10/27	2245	32° 18'	64° 38'	0-1430 dbar
174	CTD 48		2250	32° 17'	64° 38'	0-1309 dbar

Table II - KNORR 52 SCIENTIFIC OBSERVATIONS

Obs. #	Instrum. #	Date (GMT)	Time (GMT)	Approx. Launch Position Lat. (N)	Long. (W)	Comments
175	SCIMP 10	10/28	0121	32° 25'	64° 25'	0-1580-1700 m
176	EMVP 297		0137	32° 26	64° 25	0-2981 dbar
177	PROTAS 23		0134	32° 26'	64° 25'	40-1000 m
178	CTD 49	10/28	0200	32° 26'	64° 25'	0-2869 dbar
179	EMVP 298	10/28	0508	32° 25'	64° 30'	0-916 dbar
180	CTD 50		0526	32° 25'	64° 30'	0-901 dbar
181	EMVP 299	10/28	0859	32° 30.7'	64° 33'	0-1296 dbar
182	CTD 51		0855	32° 30.7'	64° 34'	0-955 dbar
183	MSR 21	10/28	1117	32° 20'	64° 33'	350-600 m
184	CTD 52		1126	32° 20'	64° 33'	0-1155 dbar
185	EMVP 300		1127	32° 20'	64° 33'	0-1182 dbar
186	CTD 53	10/30	2210	32° 09'	65° 01'	0-771 dbar
187	CTD 54	10/30	2326	32° 10'	65° 06'	0-1941 dbar
188	CTD 55	10/31	0102	32° 13'	65° 03'	0-951 dbar
189	CTD 56	10/31	0240	32° 14'	65° 06'	0-2101 dbar
190	CTD 57	10/31	0422	32° 16'	65° 04'	0-869 dbar
191	CTD 58	10/31	0527	32° 18'	65° 08'	0-1705 dbar
192	CTD 59	10/31	0707	32° 19'	65° 04'	0-991 dbar
193	CTD 60	10/31	2308	32° 15'	64° 42'	0-1301 dbar
194	EMVP 301	11/1	0124	32° 14'	64° 43'	0-1609 dbar
195	MSR 22		0119	32° 14'	64° 43'	500-725 m
196	YVETTE 1		0124	32° 14'	64° 43'	No data
197	PROTAS 24		0125	32° 14'	64° 43'	300-1000 m
198	CTD 61	11/1	0810	32° 17'	64° 38'	0-999 dbar
199	CTD 62	11/1	start 0915	32° 20'	64° 33'	0-1201 dbar
200	CTD 63	11/1	1108	32° 25'	64° 30'	0-1053 dbar
201	CTD 64	11/1	1231	32° 20'	64° 27'	0-2419 dbar
202	EMVP 302	11/1	1556	32° 11'	64° 48'	0-1803 dbar
203	XBT-FS 17		1556	32° 11'	64° 48'	
204	PROTAS 25		1603	32° 11'	64° 48'	40-1000 m
205	CAMEL 16		1605	32° 11'	64° 48'	No data
206	MSR 23		1559	32° 11'	64° 48'	500-750 m
207	CTD 65	11/1	1821	32° 11'	64° 48'	0-1615 dbar
208	EMVP 303	11/1		32° 12'	64° 47'	No data
209	MSR 24		2004	32° 12'	64° 47'	500-750 m
210	PROTAS 26		2009	32° 12'	64° 47'	280-1000 m
211	CTD 66	11/1	2252	32° 12'	64° 48'	0-1703 dbar
212	PROTAS 27	11/2	0217	32° 12'	64° 48'	280-1000 m
213	EMVP 304		0225	32° 12'	64° 48'	0-1741 dbar
214	CTD 67	11/3	1808	32° 25'	64° 25'	0-1229 dbar

Table II - KNORR 52 SCIENTIFIC OBSERVATIONS

Obs. #	Instrum. #	Date (GMT)	Time (GMT)	Approx. Launch Position Lat. (N)	Long. (W)	Comments
215	EMVP 305	11/3	1908	32° 25'	64° 25'	0-2830 dbar
216	MSR 25		1903	32° 25'	64° 25'	750-1000 m
217	PROTAS 28		1908	32° 25'	64° 25'	280-1000 m
218	XBT-FS 18		1906	32° 25'	64° 25'	
219	CAMEL 17		1910	32° 25'	64° 25'	No data
220	EMVP 306	11/4	0214	32° 59'	64° 24'	0-4576 dbar
221	MSR 26		0213	32° 59'	64° 24'	750-1000 m
222	PROTAS 29		0219	32° 59'	64° 24'	280-1000 m
223	CAMEL 18		0222	32° 59'	64° 24'	0-270 m
224	CTD 68	11/4	0509	32° 59'	64° 25'	0-3709 dbar
225	EMVP 307	11/4	0745	32° 59'	64° 24'	0-4573 dbar
226	CTD 69		0749	32° 59'	64° 24'	0-3707 dbar
227	SCIMP 11	11/4	1300	32° 58'	64° 22'	0-1050 m
228	EMVP 308		1318	32° 58'	64° 22'	0-4553 dbar
229	PROTAS 30		1315	32° 58'	64° 22'	40-1000 m
230	MSR 27		1316	32° 58'	64° 22'	750-1000 m
231	XBT-FS 19		1321	32° 58'	64° 22'	
232	CAMEL 19		1320	32° 59'	64° 22'	No data
233	YVETTE 3	11/4	1525	32° 58'	64° 22'	0-800 m, poor quality velocity
234	EMVP 309	11/4	1853	32° 58'	64° 22'	0-4551 dbar
235	MSR 28		1850	32° 58'	64° 22'	750-1000 m
236	YVETTE 4		1852	32° 58'	64° 22'	0-820 m, no velocity data
237	PROTAS 31		1855	32° 58'	64° 22'	280-1000 m
238	XBT-FS 20		1857	32° 58'	64° 22'	
239	CAMEL 20		1858	32° 58'	64° 22'	0-780 m
240	SCIMP 12	11/4	2302	32° 59'	64° 24'	0-800-1300 m
241	EMVP 310	11/5	0013	32° 59'	64° 24'	0-4568 dbar
242	PROTAS 32		0011	32° 59'	64° 24'	40-1000 m
243	CAMEL 21		0015	32° 59'	64° 24'	0-770 m, To?
244	MSR 29		0058	32° 59'	64° 24'	900-1125 m
245	EMVP 311	11/5	0635	32° 25'	64° 25'	0-2363 dbar
246	PROTAS 33	11/5	0935	32° 20'	64° 16'	40-1000 m
247	EMVP 312		0940	32° 20'	64° 16'	0-4161 dbar
248	EMVP 313	11/5	1415	32° 13'	64° 25'	0-3474 dbar
249	MSR 30		1417	32° 13'	64° 25'	No data
250	CAMEL 22		1423	32° 13'	64° 25'	No data
251	EMVP 314	11/5	1854	32° 20'	64° 33'	0-1246 dbar
252	PROTAS 34		1845	32° 20'	64° 33'	40-800 m
253	CAMEL 23		1850	32° 20'	64° 33'	0-795 m
254	AVP 1	11/5	1934	32° 19'	64° 34'	
255	YVETTE 5		1942	32° 19'	64° 34'	0-725 m, poor quality velocity
256	MSR 31		2014	32° 19'	64° 34'	300-550 m
257	SCIMP 13	11/5	2248	32° 10'	64° 42'	0-1700 m
257A	CTD 70		2250	32° 10'	64° 42'	0-1603 dbar

Table II - KNORR 52 SCIENTIFIC OBSERVATIONS

Obs. #	Instrum. #	Date (GMT)	Time (GMT)	Approx. Launch Position Lat. (N)	Long. (W)	Comments
258	PROTAS 35	11/6	0024	32° 11'	64° 42'	280-1000 m
259	EMVP 315		0050	32° 11'	64° 42'	0-2669 dbar
260	CAMEL 24		0055	32° 11'	64° 42'	0-810 m
261	EMVP 316	11/6	0359	32° 13'	64° 44'	0-1452 dbar
262	CTD 71		0400	32° 13'	64° 44'	0-1301 dbar
263	EMVP 317	11/6	0909	32° 15'	65° 06'	0-1638 dbar
264	CTD 72		0912	32° 15'	65° 06'	0-1471 dbar
265	EMVP 318	11/6	1312	32° 33'	64° 51'	0-1560 dbar
266	MSR 32		1312	32° 33'	64° 51'	300-550 m
267	PROTAS 36		1315	32° 33'	64° 51'	280-1000 m
268	CTD 73		1321	32° 33'	64° 51'	0-1555 dbar
269	SCIMP 14	11/6	1739	32° 25'	64° 25'	0-600 m
270	EMVP 319		1745	32° 25'	64° 25'	0-2868 dbar
271	AVP 2		1758	32° 25'	64° 25'	
272	MSR 33		1759	32° 25'	64° 25'	1000-1250 m
273	YVETTE 6		1802	32° 25'	64° 25'	0-920, fair quality
274	PROTAS 37		1805	32° 25'	64° 25'	40-1000 m
275	CAMEL 25		1810	32° 25'	64° 25'	No data
276	SCIMP 15	11/7	1500	35° 00'	66° 30'	0-550-1900 m
277	EMVP 320		1551	35° 00'	66° 30'	0-5136 dbar
278	AVP 3		1558	35° 00'	66° 30'	
279	MSR 34		1559	35° 00'	66° 30'	1000-1225 m
280	YVETTE 7		1604	35° 00'	66° 30'	0-920, good quality
281	XBT-FS 21		1602	35° 00'	66° 30'	
282	PROTAS 38		1606	35° 00'	66° 30'	280-1000 m
283	CAMEL 26		1609	35° 00'	66° 30'	0-340 m
284	CTD 74	11/7	1940	35° 00'	66° 31'	0-1501 dbar
285	EMVP 321	11/7	2140	35° 00'	66° 30'	No data, may be recoverable
286	AVP 4		2134	35° 00'	66° 30'	
287	PROTAS 39		2138	35° 00'	66° 30'	280-1200 m
288	MSR 35		2136	35° 00'	66° 30'	650-900 m
289	SCIMP 16		2247	35° 00'	66° 30'	0-1800 m
290	CTD 75	11/8	0055	35° 00'	66° 30'	0-2117 dbar
291	EMVP 322	11/8	0225	35° 00'	66° 30'	0-5133
292	AVP 5		0218	35° 00'	66° 30'	
293	MSR 36		0224	35° 00'	66° 30'	350-575 m
294	YVETTE 8		0225	35° 00'	66° 30'	0-740 m, good quality
295	PROTAS 40		0227	35° 00'	66° 30'	280-1200 m
296	CAMEL 27		0230	35° 00'	66° 30'	0-485 m
297	EMVP 323	11/8	0704	35° 00'	66° 30'	0-5132 dbar
298	AVP 6		0708	35° 00'	66° 30'	
299	CTD 76		0728	35° 00'	66° 31'	0-3809 dbar
300	MSR 37	11/8	1219	35° 00'	66° 30'	25-275 m
301	YVETTE 9		1219	35° 00'	66° 30'	0-930 m, good quality
302	PROTAS 41		1221	35° 00'	66° 30'	280-1200 m
303	EMVP 324		1231	35° 00'	66° 30'	0-5132 dbar
304	AVP 7		1228	35° 00'	66° 30'	
305	CAMEL 28		1236	35° 00'	66° 30'	0-600 m, T noisy

Table II - KNORR 52 SCIENTIFIC OBSERVATIONS

Obs. #	Instrum. #	Date (GMT)	Time (GMT)	Approx. Launch Position		Comments
				Lat. (N)	Long. (W)	
306	XBT 2	11/8	1700	35° 10'	66° 42'	
307	XBT 3		1830	35° 23'	66° 54'	
308	XBT 4		2000	35° 36'	67° 06'	
309	XBT 5		2130	35° 49'	67° 18'	
310	XBT 6		2300	36° 00'	67° 32'	
311	XBT 7	11/9	0030	36° 13'	67° 44'	
312	XBT 8		0200	36° 26'	67° 56'	
313	XBT 9		0330	36° 39'	68° 07'	XBT Survey to find
314	XBT 10		0500	36° 51'	68° 17'	Gulf Stream
315	XBT 11		0630	37° 04'	68° 30'	
316	XBT 12		0800	37° 15'	68° 42'	
317	XBT 13		0930	37° 26'	68° 55'	
318	XBT 14		1030	37° 34'	69° 01'	
319	XBT 15		1130	37° 43'	69° 04'	
320	XBT 16		1230	37° 54'	69° 09'	
320A	XBT 17		1330	38° 04'	69° 06'	
321	XBT 18		1400	38° 09'	69° 07'	
322	XBT 19		1430	38° 14'	69° 08'	
323	EMVP 325	11/9	1529	38° 09.0'	69° 06'	0-3871 dbar
324	XBT-FS 22		1522	38° 09.0'	69° 06'	
325	CAMEL 29		1525	38° 09'	69° 06'	0-440 m, T noisy
326	YVETTE 10	11/9	1814	38° 09'	69° 06'	0-900 m
327	XBT-FS 23		1815	38° 09'	69° 06'	
328	PROTAS 42		1816	38° 09'	69° 06'	40-1000 m
329	MSR 38	11/9	2002	38° 09'	69° 02'	25-275 m
330	XBT-FS 24		2003	38° 09'	69° 02'	
331	SCIMP 17		2000	38° 09'	69° 02'	0-700 m
332	PROTAS 43	11/9	2133	38° 08'	68° 58'	40-1000 m
333	XBT 20	11/10	0028	38° 05'	69° 03'	
334	SCIMP 18		0032	38° 05'	69° 03'	0-650 m
335	YVETTE 11		0036	38° 05'	69° 03'	0-1160 m, good quality
336	PROTAS 44		0037	38° 05'	69° 03'	40-1000 m
337	MSR 39		0044	38° 04'	69° 00'	25-250 m
338	EMVP 326		0047	38° 04'	69° 00'	0-3949 dbar
339	CAMEL 30		0115	38° 04'	69° 04'	0-535, T noisy
340	EMVP 327	11/10	0442	38° 05'	69° 04'	0-3954 dbar
341	MSR 40		0444	38° 05'	69° 04'	250-500 m
342	CTD 77		0450	38° 05'	69° 04'	0-1605 dbar
343	EMVP 328	11/10	0816	37° 59'	69° 05'	0-3997 dbar
344	CTD 78		0813	37° 59'	69° 04'	0-3717 dbar
345	XBT 21	11/10	1100	38° 04'	69° 03'	
346	XBT 22		1130	38° 08'	69° 05'	
347	XBT 23		1200	38° 13'	69° 07'	
348	CTD 79	11/10	1210	38° 14'	69° 08'	0-1005 dbar
349	SCIMP 19	11/10	1305	38° 15'	69° 07'	0-700 m
350	EMVP 329		1320	38° 15'	69° 07'	0-3789 dbar
351	YVETTE 12		1312	38° 15'	69° 07'	0-1100 m, good quality
352	PROTAS 45		1315	38° 15'	69° 07'	40-1000 m
353	CAMEL 31		1320	38° 15'	69° 07'	0-540, T noisy

Table III

KNORR METEOROLOGICAL OBSERVATIONS

Table Key:

WIND FORCE CODE - BEAUFORT'S SCALE AND VELOCITY (WMO Code 30)

Code	Description	Knots
0	Calm	Less than 1.
1	Light air	1 to 3.
2	Light breeze	4 to 6.
3	Gentle breeze	7 to 10.
4	Moderate breeze	11 to 16.
5	Fresh breeze	17 to 21.
6	Strong breeze	22 to 27.
7	Moderate gale	28 to 33.
8	Fresh gale	34 to 40.
9	Strong gale	41 to 47.
10	Whole gale	48 to 55.
11	Storm	56 to 63.
12	Hurricane	64 to 71.
13	do	72 to 80.
14	do	81 to 89.
15	do	90 to 99.
16	do	100 to 109.
17	do	110 to 118.

STATE OF SEA - WIND WAVES (WMO Code 75)

Code	Description	Height	
		Feet	Meters
0	Calm—glassy	0	0
1	Calm—ripples	0–1/3	0–1/10
2	Smooth—wavelets	1/3–1 2/3	1/10–1/2
3	Slight	1 2/3–4	1/2–1 1/4
4	Moderate	4–8	1 1/4–2 1/2
5	Rough	8–13	2 1/2–4
6	Very rough	13–20	4–6
7	High	20–30	6–9
8	Very high	30–45	9–14
9	Phenomenal	over 45	over 14

NOTE: The exact bounding height is to be assigned to the lower code figure, that is, a height of 4 feet is coded as 3.

SWELL CONDITION CODE

Code	Height in feet	Description	Approximate length in feet
0	0—no swell		0.
1	1 to 6—low swell	Short or average	0 to 600.
2		Long	Above 600.
3	6 to 12—moderate	Short	0 to 300.
4		Average	300 to 600.
5		Long	Above 600.
6	Greater than 12—high	Short	0 to 300.
7		Average	300 to 600.
8		Long	Above 600.
9	Confused		

WEATHER

- **b** blue sky, whether with clear or hazy atmosphere.
- **c** cloudy, i.e., detached opening clouds.
- **d** drizzle.
- **e** wet air without rain falling, a copious deposit of water on trees, buildings or rigging.
- **f** fog.
- **fe** wet fog.
- **g** gloom.
- **h** hail.
- **l** lightning.
- **m** mist; range of visibility 1,100 yards or more, but less than 2,200 yards.
- **o** overcast, i.e., the whole sky covered with one impervious cloud.
- **p** passing showers.
- **q** squalls.
- **KQ** line squall.
- **r** rain.
- **rs** sleet, i.e., rain and snow together.
- **s** snow.
- **t** thunder.
- **tl** thunderstorm.
- **u** ugly, threatening sky.
- **v** unusual visibility of distant objects.
- **w** dew.
- **x** hoar frost.
- **y** dry air (less than 60 per cent. humidity).
- **z** haze; range of visibility 1,100 yards or more, but less than 2,200 yards.

Beaufort used small letters in his notation but under the new convention a capital letter is used to denote intensity of the phenomenon to be noted; at the other end of the scale occasions of slight intensity are indicated by a small suffix $_0$. Continuity is indicated by a repetition of the letter and intermittence by prefixing the letter i. Thus we have :—

- R heavy rain.
- r (moderate) rain.
- r_0 slight rain.
- RR continuous heavy rain.
- rr continuous (moderate) rain.
- ir_0 intermittent slight rain.

For further details in the interpretation of the Beaufort Notation see the "Meteorological Observer's Handbook."

Table III

KNORR 52 - METEOROLOGICAL OBSERVATIONS

GMT Date	GMT Time	Wind and Force	Sea State	Swell and Dir.	Bar.	Air Temp.	Water Temp.	Weather	Remarks
10/15	1600	SW/2			29.88	20.6		BC	
	2000								
10/16	0000	SW/4	3	SW/2	29.88	16.7	16.1	Z	Vis. Fair
	0400	SW/4	3	SW/2	29.86	18.7		Z	Poor Vis. in haze
	0800	WSW/5	3	SW/2	29.87	19.4	18.3	BCZ	Vis. Fair in haze
	1200	SW×S/4	4	SW/2	29.90	20.0	18.3	BCZ	Vis. Fair
	1600	WSW/4	3	SW/2	29.93	26.1		BCZ	Good Vis. - Light haze
	2000	WNW/5	3	W/2	29.94	29.3	21.7	BCZ	Vis. Fair
10/17	0000	W×N/4	3	W×S/2	30.03	21.1	21.1	BC	Vis. Good
	0400	NW×N/4	3	W/2	30.10	21.1	21.1	BC	" "
	0800	S×W/2	2	W/2	30.08	19.4	18.9	CZ	" "
	1200	E/2	2	W/2	30.14	21.7	23.9	BZ	" "
	1600	SW/1-2	2	W/2	30.18	26.1	23.9	BC	" "
	2000	SW/3	2	W/2	30.15	25.6	23.9	BC	" "
10/18	0000	SW/2	2	SW/2	30.18	23.3	23.3	BC	" "
	0400	SSE/4	2	SW/2	30.19	25.0	23.3	BC	" "
	0800	SSE/3	2	S×E/2	30.16	23.9	23.9	C-Z	Vis. Fair in haze
	1200	SSE/3	3	SSE/2	30.17	23.9	23.9	B-C	Vis. Good
	1600	SSE/5	3	SSE/2	30.15	26.7	23.3	BC	" "
	2000	SSE/6	3	SSE/3	30.10	26.1	23.9	CZ	" "
10/19	0000	SSE/6	4	SSE/3	30.07	20.0	24.4	OP	" "
	0400	SSE/6	5	SSE/3	30.05	25.6	23.3	C	" "
	0800	S×E/7	5	SSE/5	29.98	23.3	23.3	O-P-Z	Vis. Poor-Rain squalls
	0200		5		30.00	23.3	23.3	OP	Vis. Good
	1600	S-W/4	5	W/4	30.03	26.7		BC	" "
	2000	SW/4-5	5	W/4	30.02	26.1	24.4	BC	" "
10/20	0000	W×S/3	2	S/4	30.02	24.4	24.4	BC	" "
	0400	WSW/4	2	W/4	30.02	26.1	24.4	BC	" "
	0800	WSW/4	2	W/3	29.98	24.4	23.8	BC	" "
	1200	WSW/3	2	W/2	29.99	23.3	23.9	C	" "
	1600	S/3	2	W/2	29.99	25.6	23.3	C	" "
	2000	SSW/4	2	W/2	29.92	23.9	23.9	O-P	" "
10/21	0000	WNW/5	3	W/2	29.93	21.7		O	" "
	0400	WNW/3-4	2	W/2	29.96	23.3		BC	" "
	0800	W×N/5	3	W/3	29.96	23.3	23.9	C	" "
	1200	WNW/5	3	WNW/3	30.00	22.2	23.9	BC	" "
	1600	WNW/5	3	WNW/4	30.06	25.9		BC	" "
	2000	NW/4	3	WNW/4	30.03	21.1	23.9	BC	" "
10/22	0000	WNW/3	3	W/4	30.05	20.0	23.9	BC	" "
	0400	NW/2-3	2	W/2	30.08	23.3		BC	" "
	0800	VAR/1	2	E/2	30.06	21.7	23.9		" "
	1200	NW/1	1	E/2	30.06	22.2	23.9	O	" "
	1600	VAR/1-2	1	E/2	30.10	22.8	23.9	O	" "
	2000	W/1-2	1	E/2	30.07	22.2	23.9	O	" "

Table III

KNORR 52 - METEOROLOGICAL OBSERVATIONS (Contd.)

GMT Date	Time	Wind and Force	Sea State	Swell and Dir.	Bar.	Air Temp.	Water Temp.	Weather	Remarks
10/23	0000	VAR/1	1	E/2	30.10	21.1	23.9	BC	Vis. Good
	0400	SW/2	1	E/2	30.11	23.3	23.9	BC	" "
	0800	S/2	1	E/2	30.13	22.2	23.9	CZ	Vis. Fair in haze
	1200	VAR/1	1	E/2	30.15	21.9	23.9	C	Vis. Good
	1600	SE/3	1	E/2	30.20	25.0	23.9	C	" "
	2000	E/3	1	E/2	30.20	23.9	23.3	O	" "
10/24	0000	E/4	3	E/2	30.23	22.8	23.9	O	" "
	0400	ESE/4	3	E/2	30.25	21.1	23.3	O/D	" "
	0800	E×S/5	3	E/3	30.24	22.8	23.3	O	" "
	1200	E×S/4	3	E×S/3	30.28	22.2	23.9	OP	" "
	1600	E×N/6	3	E/3	30.30	23.9	23.3	O-P	Passing Rain Squalls
	2000	E×S/5	3	E/3	30.29	25.6	23.9	O	Vis. Good
10/25	0000	E×S/5	3	E/2	30.31	23.9	23.3	O	" "
	0400	ESE/5	2	E/2	30.30	23.3	23.3	BC	" "
	0800	E/6	3	E/3	30.27	23.9	23.3	OQ	" "
	1200	E×S/5	3	E×S/3	30.29	23.3	23.3	BC	" "
	1600	E×S/5	3	E×S/3	30.31	25.0	23.3	BC	" "
	2000	E×S/5	3	E×S/3	30.26	24.4	23.3	O	" "
10/26	0000	ESE/4	3	E/2	30.28	23.3	23.3	O	" "
	0400	ESE/3-4	2	E/2	30.24	23.9	23.3	BC	" "
	0800	ESE/3	2	E/2	30.20	23.9	23.3	C	" "
	1200	SSE/3	2	E/2	30.22	23.9	23.9	B	" "
	1600	E/3	2	E/2	30.20	26.1	-	BC	" "
	2000	SSE/3	2	SE/2	30.17	25.6	23.9	BC	" "
10/27	0000	SSE/2	1	SE/1	30.17	24.4	23.3	BC	" "
	0400	S/1	1	SE/2	30.16	24.4	23.3	BC	" "
	0800	S/1-2	1	E/1	30.16	23.9	23.9	BC	" "
	1200	SW/3	1	E/2	30.19	23.9	23.3	BC	" "
	1600	S×W/3	1	E/2	30.20	26.7	23.3	BC	" "
	2000	S/1-2	1	E/2	30.17	26.7	23.6	BC	" "
10/28	0000	S/1	1	E/2	30.20	23.9	23.3	BC	" "
	0400	S×W/3	1	E/2	30.20	24.4	23.3	BC	" "
	0800	S×W/3	1	E/2	30.17	25.0	25.3	C	" "
	1200	S/1	1	E/2	30.20	23.3	24.4	BC	" "
	1600	S/1-2			30.21	28.9		BC	IN PORT
	2000	S/3			30.19	27.2		BC	" "
10/29	0000	AIRS			30.20	22.8		BC	" "
	0400	SW/2			30.18	22.2		BC	" "
	0800	SW/2			30.15	22.2		BC	" "
	1200	AIRS			30.17	23.9		BC	" "
	1600	SW/3			30.15	26.1		BC	" "
	2000	W/2			30.11	27.2		BC	" "

Table III

KNORR 52 - METEOROLOGICAL OBSERVATIONS (Contd.)

GMT Date	Time	Wind and Force	Sea State	Swell and Dir.	Bar.	Air Temp.	Water Temp.	Weather	Remarks
10/30	0000	SW/2			30.13	23.9		BC	IN PORT
	0400	AIRS			30.13	23.9		BC	" "
	0800	SW/3			30.05	22.8		BC	" "
	1200	SW/3			30.03	23.9		BC	" "
	1600	SW/3			29.98	25.6		BC	" "
	2000	S/4	2	S/3	29.92	26.7		BC	Vis. Good
10/31	0000	SSW/5	3	S/3	29.90	25.6	24.4	BC	" "
	0400	WSW/4	3	E/3	29.38	21.7	23.3	I/P	Vis. Good & Rain Squalls
	0800	WNW/5	3	SW/3	29.86	22.8	23.9		
	1200	WNW/5	3	E/2	29.92	20.0	23.9		
	1600	WNW/7	4	NW/4	30.00	22.2			
	2000	NNW/7	-	-	30.02	22.6			
11/1	0000	N/5-6	3	N/2	30.10	20.0	23.9		
	0400	NNE/5	3	N/2	30.18	21.1	23.9		
	0800	NNE/4	3	N/2	30.19	20.6	23.9	C	Vis. Good
	1200	NNE/5	3	N/3	30.23	19.4		C	" "
	1600	NNE/5	3	N/4	30.26		23.9	C	" "
	2000	NE/6	3	NE/3	30.25	21.1	23.9	CQ	Vis. Fair
11/2	0000	ENE/5	3	ENE/3	30.25	20.6		O	" "
	0400	ENE/4	3	ENE/2	30.28	20.6	23.7	BC	Vis. Good
	0800	NE/4	2	NE/2	30.23	21.1	23.9		" "
	1200	N/4	3	E/2	30.26	20.0	23.3	BC	Vis. Excellent
	1600	NE/4	3	E/2	30.26	29.4	23.3	BC	Vis. Good
	2000	NE/3	3	N/3	30.19	23.3	23.3	BC	" "
11/3	0000	ENE/5	4	ENE/4	30.20	22.2	23.3	C	" "
	0400	ENE/5	4	ENE/4	30.20	23.9	23.3	BC	" "
	0800	E×N/5	4	ENE/4	30.19	23.3	23.3	BC	" "
	1200	E×N/5-6	4	E×N/4	30.24	21.1	22.8	BC	" "
	1600	E×N/4	3	E/4	30.28	27.2		BC	" "
	2000	NE/3	3	NE/4	30.27	23.3	23.3	BC	" "
11/4	0000	NE×E/4	3	NE/4	30.25	21.1	24.4	BC	" "
	0400	ENE/3-4	3	E/2	30.25	22.8	24.4	BC	" "
	0800	ENE/3	3	E/2	30.23	22.2	23.3	BC	" "
	1200	ENE/3	2	E/2	30.25	22.2	23.3	BC	" "
	1600	ENE/2	2	E/2	30.26	30.6	23.5	BC	" "
	2000	NE/1-2	2	E/2	30.22	24.4	23.3	BC	" "
11/5	0000	ENE/1	1	E/2	30.22	20.6	23.3	B	Vis. Excellent
	0400	ENE/1-2	1	E/2	30.18	20.6	23.0	BC	" "
	0800	WNW/2	1	NE/1	30.14	21.1	23.9	BC	Vis. Good
	1200	WNW/3	2	E/2	30.15	22.8	23.3	BC	Vis. Excellent
	1600	WNW/3	2	E/2	30.13	31.1	23.3	BC	" "
	2000	NNW/4	2	NW/2	30.07	24.4	22.8	C	Vis. Good

Table III

KNORR 52 - METEOROLOGICAL OBSERVATIONS (Contd.)

GMT Date	Time	Wind and Force	Sea State	Swell and Dir.	Bar.	Air Temp.	Water Temp.	Weather	Remarks
11/6	0000	WNW/3	2	NW/2	30.07	23.3	22.8	BC	Vis. Good
	0400	N-W/4-5	2	NW/2	30.08	23.3	23.3	BC	" "
	0800	NW/4-5	3	NW/3	30.07	22.8	23.3	BC	" "
	1200	N/3	3	N/4	30.13	23.3	22.8	O	" "
	1600	N/4	3	E/4	30.18	23.9	23.3	BC	" "
	2000	NNE/4	3	NW/4	30.17	23.9	23.3	C	" "
11/7	0000	NNE/3	3	NW/4	30.20	20.0	22.8	BC	" "
	0400	NE/3	3	N×W/3	30.25	21.1	22.2	BC	" "
	0900	NE×E/4	3	NW/3	30.28	20.6	23.3	C	" "
	1300	NE×E/1	1	NE/2	30.33	21.1	22.8	BC	" "
	1700	SE×E/3	1	E/2	30.34	22.2	22.8	BC	" "
	2100	SE/1-2	1	E/2	30.32	21.7	22.8	BC	" "
11/8	0100	ESE/2	1	E/2	30.35	23.9	23.3	BC	" "
	0500	VARIOUS/3	1	E/2	30.35	23.9	23.3	BC	" "
	0900	SE/3	2	E/2	30.30	21.1	23.3	BC	" "
	1300	SE/2	1	SE/2	30.33	22.2	23.3	O	" "
	1700	S/2	1	SE/2	30.29	23.3	22.8	BC	" "
	2100	SSE/2	1	SE/2	30.25	23.3	24.4	C	" "
11/9	0100	SSW/3	2	SSW/2	30.25	21.1	24.4	O	" "
	0500	S/4	3	SSW/2	30.21	21.7	23.3	BC/L	Vis. Good-Distant Lightening
	0900	WSW/4	3	SW/3	30.20	21.7	22.8	C-P	Vis. Fair to Good - Passing showers
	1300	VARIOUS/2	1	E/2	30.23	21.1	26.1	OP	Vis. Fair to Good
	1700	S/2	1	E/2	30.23	22.2	25.0	BC	Vis. Good
	2100	AIRS	1	E/2	30.23	23.3	23.9	BC	" "
11/10	0100	AIRS	1	E/2	30.25	21.1	24.4	O/P	" "
	0500	VAR/1-4	1	E/2	30.25	21.1	24.4	O/P	" "
	0900	SSW/4	1	E/2	30.23	23.3	22.8	BCF	Visability Poor
	1300	AIRS	O	E/2	30.25	22.2	24.4	BCP	Visability Good
	1700	AIRS	1	E/2	30.19	25.0	24.4	BC	Visability Excellent
	2100	SSW/4	1	E/2	30.12	20.6	20.0	BC	Visability Good
11/11	0100	SSW/6	3	SSW/2	30.06	20.6	22.8	O	" "
	0500	SSW/6	3	E/2	30.00	18.3		O/M	Visability Fair - Light mist
	0900	NW/4	3	E/2	30.01	13.9	14.4	BC	Visability Good
	1300	WNW/5	3	E/2	30.09	12.8	15.0	BC	Visability Excellent

C. Cruise Report and Observation Log for the R/V Eastward

After being delayed most of one day by winch problems, the Eastward sailed from Beaufort, N. C. at 7:00 A.M. Monday, October 13. We initially set course due east along 34° 30' N towing a geomagnetic electrokinetograph (GEK) and taking XBTs every two hours. After encountering a Gulf Stream ring and testing our CTD systems at 70° 30' W, we turned on a more southward track and headed straight for Bermuda, arriving there on October 17.

We commenced taking CTDs on the 2000 m and 1000 m depth contours and XBTs at 500 m depth for 16 "spokes" radiating out from the island. Study of the resulting profiles indicated that the most intense fine structure existed on the northwest slope. On October 20 Eli Katz on the Chain arrived in the area. Our results were discussed via radio and it was decided to make two tows with his system through the active area that we had uncovered.

The Eastward then began circuits at 50 and 75 km with an additional 32 CTD stations. We rendezvoused with the Knorr October 24, had a brief conference, and then completed our work before entering St. George's on October 28. An additional circumnavigation of the island, towing the GEK and taking XBTs was also performed.

After some rest, relaxation and a scientific conference with the Knorr scientific party, we left port on October 30. Until November 5 we deployed and tracked five neutrally buoyant Swallow floats on the western side of the island and reoccupied CTD stations on the 50 km circuit. November 5 we left the area for Beaufort, again towing the GEK and taking XBTs every four hours. We arrived back in Beaufort in late afternoon of November 8. Results of the two Beaufort-Bermuda sections have been reported by Hogg and Dunlap (1976) and discussed by Richardson (1976).

All of the Eastward station or observation locations and those around Bermuda are presented in Fig. 5 and Fig. 6. Station information is given in Table IV.

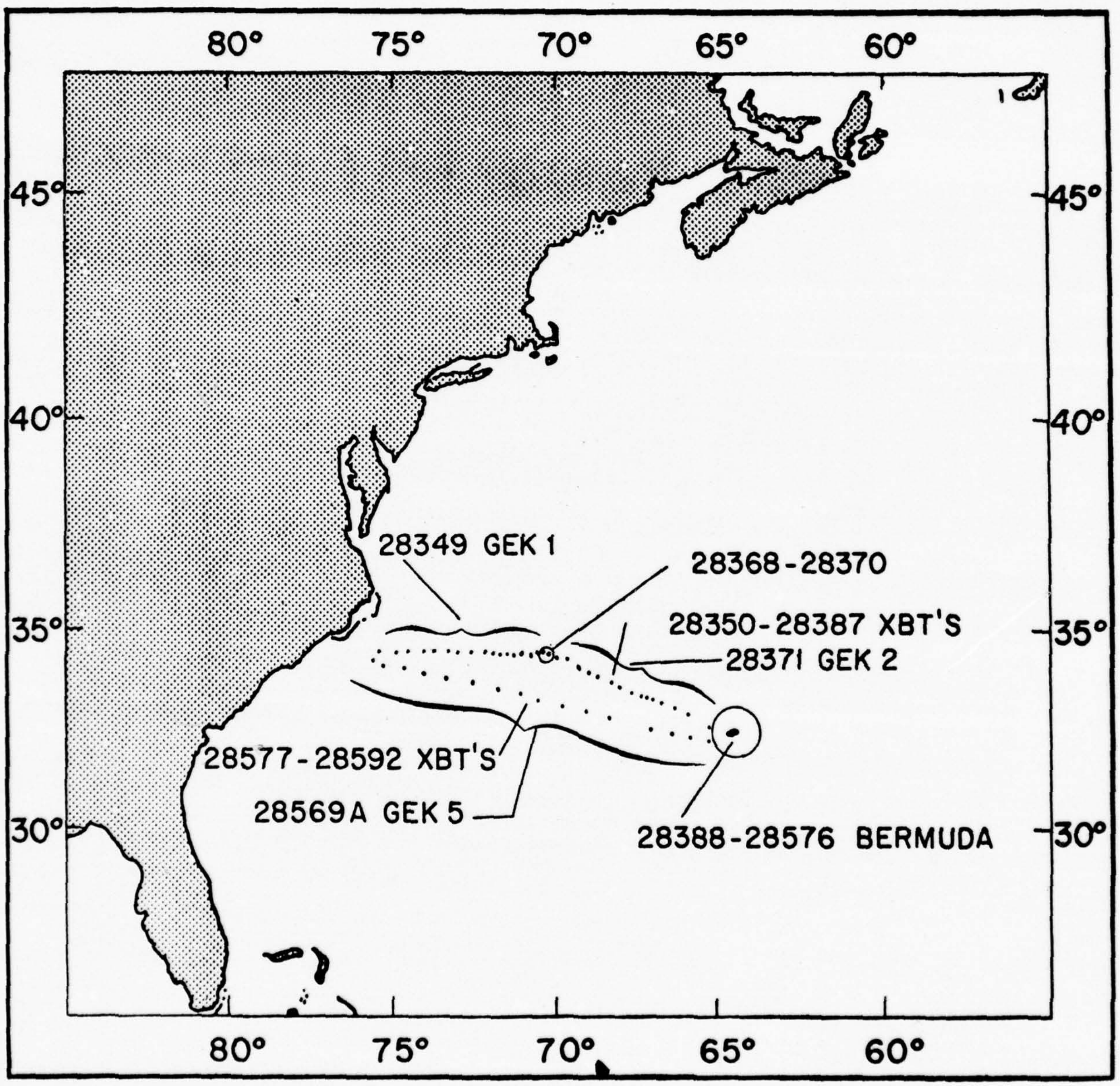

Fig. 5. R/V Eastward 12-75. Observation Nos. 28349-28592, 14 Oct. - 8 Nov., 1975

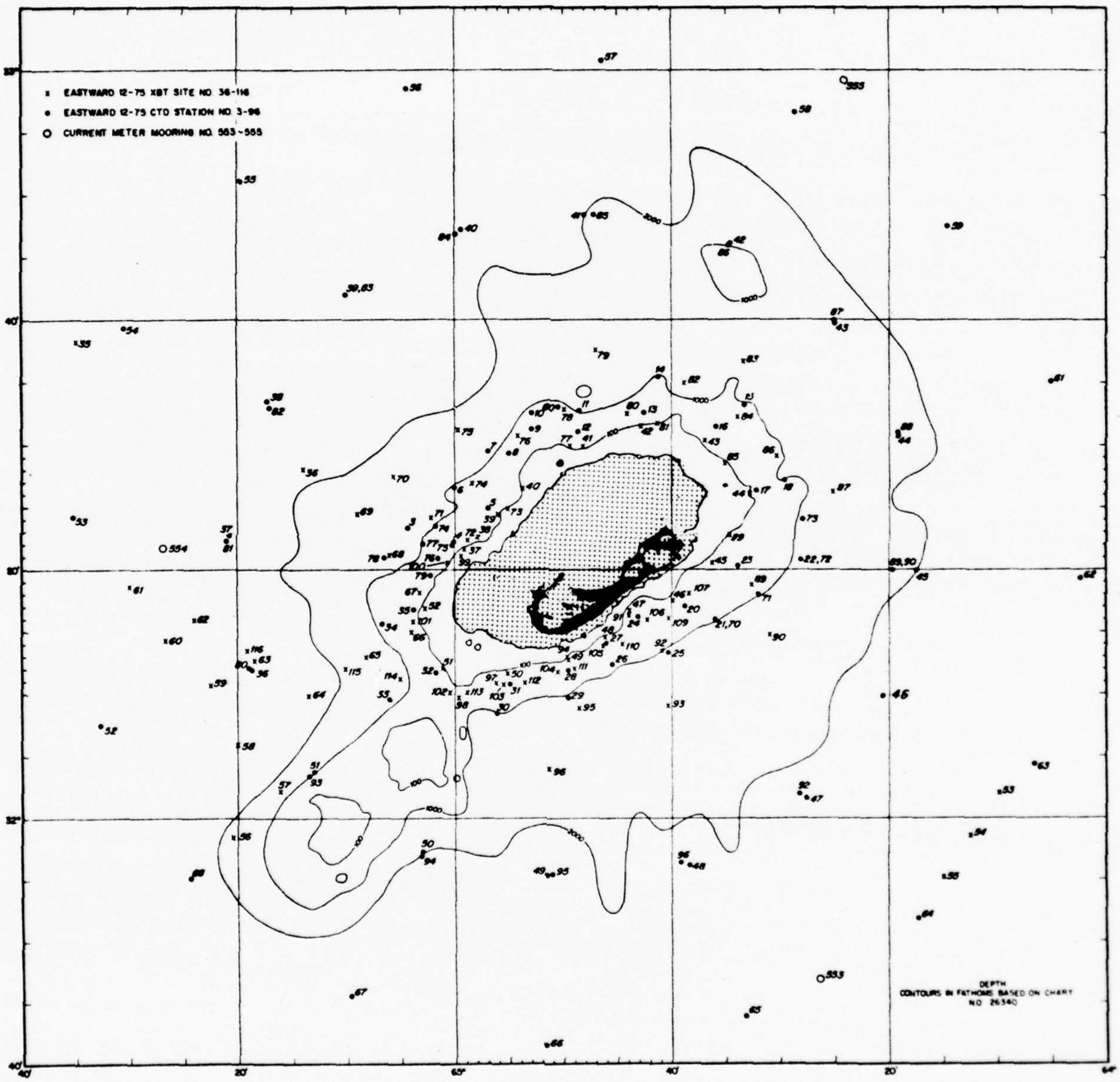

Fig. 6. R/V Eastward 12-75. CTD and XBT observations near Bermuda 17 Oct. - 5 Nov. 1975. Positions of moorings 553, 554, and 555 are also shown.

Table IV

EASTWARD 12-75 SCIENTIFIC OBSERVATIONS

Table Key:

This memo is compiled from the blue bound Cruise Log, Vols. I, II.

Instrument abbreviations:

CTD - Neil Brown-type conductivity, temperature and depth recorder (W.H.O.I. #3)

GEK - Towed geomagnetic electrokinetograph (salt-bridge type)

GV - XBT's for G. Volkmann to see depth accuracy

SF - "Swallow" floats - 10 inch glass spheres at 500 m

XBT - Sippican expendable bathythermographs

"SLO" ≡ fine structure XBT

Positions are in degrees, minutes and tenths of minutes using LORAN-C.

Depths are using a sonic recorder with sound velocity corrections included.

Table IV - RV/EASTWARD 12-75 SCIENTIFIC EVENTS

Consec. Obs.#	Inst. Obs.#	Date	Start Time (GMT)	Launch Position		Bottom Depth Cor Meters	Comments/Quality
				Lat.	Long.		
28349	GEK 1	14 Oct	1319	34°29.2N	76°12.3W	36	Thru XBT 18
28350	XBT 1	14 Oct	1641	34°30.0N	75°31.2W	2127	
28351	XBT 2	14 Oct	1900	34°29.5N	74°59.8W	3007	
28352	XBT 3	14 Oct	2100	34°29.0N	74°38.8W	3363	
28353	XBT 4	14 Oct	2300	34°30.2N	74°12.1W	3638	
28354	XBT 5	15 Oct	0100	34°30.0N	73°50.8W	3868	
28355	XBT 6	15 Oct	0300	34°29.5N	73°27.0W	4184	
28356	XBT 7	15 Oct	0459	34°30.0N	73°03.0W	4459	
28357	XBT 8	15 Oct	0659	34°29.0N	72°38.5W	4562	
28358	XBT 9	15 Oct	0859	34°30.3N	72°14.0W	4500	
28359	XBT 10	15 Oct	1000	34°30.0N	72°01.2W	4448	
28360	XBT 11	15 Oct	1100	34°30.6N	71°48.9W	4479	
28361	XBT 12	15 Oct	1200	34°30.0N	71°35.8W	4582	
28362	XBT 13	15 Oct	1300	34°30.0N	71°24.2W	4832	
28363	XBT 14	15 Oct	1400	34°29.5N	71°12.0W	4992	
28364	XBT 15	15 Oct	1500	34°27.5N	70°57.5W	5092	Radio Noise
28365	XBT 16	15 Oct	1558	34°26.9N	70°42.0W	5242	
28366	XBT 17	15 Oct	1700	34°29.7N	70°30.0W	5292	
28367	XBT 18	15 Oct	1718	34°31.5N	70°27.9W	5267	NG >540 m
28368	CTD 1	15 Oct	1745	34°32.1N	70°30.0W	5242	
28369	CTD 2	15 Oct	2000	34°35.0N	70°30.0W	5212	NRL's CTD
28370	Satelt. Buoy	15 Oct	2215	34°38.9N	70°27.8W	5142	
28371	GEK 2	15 Oct	2235	34°38.9N	70°27.8W	5142	Thru XBT 36
28372	XBT 19	15 Oct	2300	34°38.1N	70°25.0W	5172	
28373	XBT 20	16 Oct	0100	34°30.5N	70°07.8W	5282	
28374	XBT 21	16 Oct	0300	34°22.0N	69°48.3W	5342	
28375	XBT 22	16 Oct	0500	34°10.5N	69°26.2W	5352	
28376	XBT 23	16 Oct	0701	34°04.0N	69°04.0W	5342	
28377	XBT 24	16 Oct	0900	33°55.8N	68°43.6W	5317	
28378	XBT 25	16 Oct	1100	33°47.8N	68°23.0W	5292	
28379	XBT 26	16 Oct	1300	33°39.5N	68°02.2W	5217	
28380	XBT 27	16 Oct	1500	33°30.0N	67°42.0W	5162	NG >690
28381	XBT 28	16 Oct	1700	33°23.9N	67°23.6W	5117	
28382	XBT 29	16 Oct	1800	33°19.9N	67°14.1W	5042	

Table IV - RV/EASTWARD 12-75 SCIENTIFIC EVENTS

Consec. Obs.#	Inst. Obs.#	Date	Start Time (GMT)	Launch Position Lat.	Long.	Bottom Depth Cor Meters	Comments/Quality
28383	XBT 30	16 Oct	1900	33°15.1N	67°02.0W	5067	Paper Slip
28384	XBT 31	16 Oct	2100	33°11.0N	66°44.0W	5017	
28385	XBT 32	16 Oct	2300	33°02.5N	66°22.8W	4942	
28386	XBT 33	17 Oct	0115	32°49.0N	65°57.8W	4942	NG >460 m
28387	XBT 34	17 Oct	0200	32°48.0N	65°55.2W	4542	NG
28388	XBT 35	17 Oct	0400	32°38.0N	65°35.2W	4760	NG
28389	XBT 36	17 Oct	0600	32°27.8N	65°14.2W	4276	
28390	CTD 3	17 Oct	0700	32°23.1N	65°04.6W	2002	
28391	CTD 4	17 Oct	0926	32°21.9N	65°00.8W	964	
28392	XBT 37	17 Oct	1011	32°21.7N	64°59.5W	----	
28393	XBT 38	17 Oct	1020	32°22.4N	64°58.2W	733	
28394	XBT 39	17 Oct	1044	32°24.4N	64°56.2W	487	
28395	CTD 5	17 Oct	1100	32°24.8N	64°57.1W	1004	
28396	CTD 6	17 Oct	1242	32°26.4N	65°00.5W	1953	
28397	CTD 7	17 Oct	1512	32°29.3N	64°57.1W	1784	
28398	CTD 8	17 Oct	1703	32°29.3N	64°55.2W	1014	
28399	XBT 40	17 Oct	1723	32°26.3N	64°54.0W	502	Paper Slip
28400	CTD 9	17 Oct	1909	32°31.1N	64°53.1W	944	
28401	CTD 10	17 Oct	2012	32°32.4N	64°53.0W	2222	
28402	CTD 11	17 Oct	2240	32°32.7N	64°48.5W	1963	
28403	CTD 12	18 Oct	0035	32°31.0N	64°48.8W	984	
28404	XBT 41	18 Oct	0132	32°29.8N	64°48.3W	502	
28405	XBT 42	18 Oct	0226	32°31.5N	64°42.8W	502	
28406	CTD 13	18 Oct	0234	32°32.5N	64°42.5W	1024	
28407	CTD 14	18 Oct	0357	32°35.4N	64°41.1W	2032	
28408	CTD 15	18 Oct	0635	32°33.2N	64°33.3W	1824	
28409	CTD 16	18 Oct	0811	32°31.4N	64°36.1W	994	
28410	XBT 43	18 Oct	0959	32°30.5N	64°37.0W	502	NG >370
28411	XBT 44	18 Oct	1019	32°26.1N	64°32.8W	552	
28412	CTD 17	18 Oct	1036	32°26.4N	64°32.0W	1184	
28413	CTD 18	18 Oct	1235	32°27.2N	64°29.5W	2014	
28414	CTD 19	18 Oct	1519	32°20.5N	64°28.9W	1954	Aborted
28415	XBT 45	18 Oct	1645	32°20.6N	64°36.3W	502	
28416	XBT 46	18 Oct	1725	32°17.5N	64°39.9W	502	
28417	CTD 20	18 Oct	1805	32°17.0N	64°38.7W	____	Sensors shielded

Table IV - RV/EASTWARD 12-75 SCIENTIFIC EVENTS

Consec. Obs.#	Inst. Obs.#	Date	Start Time (GMT)	Launch Position Lat.	Launch Position Long.	Bottom Depth Cor Meters	Comments/Quality
28418	CTD 21	18 Oct	1910	32°16.0N	64°36.0W	1943	Sensors shielded
28419	CTD 22	18 Oct	2151	32°20.8N	64°28.2W	2002	
28419A	CTD 23	18 Oct	2045	32°20.3N	64°33.8W	1054	
28420	XBT 47	19 Oct	0333	32°16.7N	64°44.0W	502	
28421	CTD 24	19 Oct	0346	32°16.2N	64°43.0W	----	
28422	CTD 25	19 Oct	0600	32°13.2N	64°40.1W	2052	
28423	CTD 26	19 Oct	0830	32°12.3N	64°45.3W	1977	
28424	CTD 27	19 Oct	1036	32°13.9N	64°45.9W	1004	
28425	XBT 48	19 Oct	1149	32°14.5N	64°46.2W	502	
28426	XBT 49	19 Oct	1239	32°12.8N	64°49.5W	502	
28427	CTD 28	19 Oct	1302	32°11.8N	64°49.5W	1014	
28428	CTD 29	19 Oct	1434	32°09.7N	64°49.5W	2002	
28429	CTD 30	19 Oct	1711	32°08.3N	64°56.2W	2052	
28430	CTD 31	19 Oct	1933	32°10.7N	64°54.9W	904	
28431	XBT 50	19 Oct	2057	32°11.5N	64°55.4W	502	
28432	XBT 51	19 Oct	2154	32°12.0N	65°01.3W	602	
28433	CTD 32	19 Oct	2207	32°11.5N	65°01.8W	1054	
28434	CTD 33	19 Oct	2330	32°09.4N	65°06.0W	1963	
28435	CTD 34	20 Oct	0226	32°15.5N	65°06.9W	1982	
28436	CTD 35	20 Oct	0432	32°16.5N	65°03.9W	1002	
28437	XBT 52	20 Oct	0543	32°16.7N	65°03.0W	502	
28437A	CTD 36	20 Oct	0740	32°11.7N	65°18.9W	4655	
28438	CTD 37	20 Oct	1632	32°22.5N	65°20.8W	4660	
28439	CTD 38	20 Oct	2155	32°33.2N	65°17.4W	4686	
28440	CTD 39	21 Oct	0156	32°41.7N	65°10.2W	4660	
28441	CTD 40	21 Oct	0550	32°47.0N	64°59.5W	4427	
28442	CTD 41	21 Oct	1024	32°48.5N	64°47.1W	3994	
28443	CTD 42	21 Oct	1359	32°46.0N	64°34.8W	1784	
28444	CTD 43	21 Oct	1659	32°39.5N	64°25.0W	3513	
28445	CTD 44	21 Oct	2030	32°30.8N	64°19.2W	3714	
28446	CTD 45	22 Oct	0014	32°20.0N	64°17.5W	3919	
28447	CTD 46	22 Oct	0334	32°09.9N	64°20.5W	4143	
28448	CTD 47	22 Oct	0720	32°01.7N	64°27.7W	3898	
28449	CTD 48	22 Oct	1055	31°56.3N	64°38.2W	4010	
28450	CTD 49	22 Oct	1530	31°55.5N	64°51.3W	4020	
28451	CTD 50	22 Oct	1940	31°57.1N	65°02.9W	3473	

Table IV - RV/EASTWARD 12-75 SCIENTIFIC EVENTS

Consec. Obs.#	Inst. Obs.#	Date	Start Time (GMT)	Launch Position Lat.	Launch Position Long.	Bottom Depth Cor Meters	Comments/Quality
28452	CTD 51	22 Oct	2205	32°03.5N	65°13.1W	1604	
28453	CTD 52	23 Oct	0146	32°07.2N	65°32.8W	4842	
28454	CTD 53	23 Oct	0644	32°23.8N	65°35.5W	4842	
28455	CTD 54	23 Oct	1150	32°38.9N	65°30.3W	4782	
28456	CTD 55	23 Oct	1624	32°50.9N	65°19.8W	4740	
28457	CTD 56	23 Oct	2105	32°58.4N	65°04.4W	4692	
28458	CTD 57	24 Oct	0635	33°00.5N	64°46.2W	4634	
28459	CTD 58	24 Oct	1058	32°56.5N	64°28.6W	4500	
28460	CTD 59	24 Oct	1409	32°47.5N	64°14.5W	4377	
28461	CTD 60	25 Oct	0019	32°32.9N	64°50.5W	2012	
28462	GEK 3	25 Oct	0250	32°33.3N	64°49.9W	2002	
28463	CTD 61	25 Oct	0830	32°35.2N	64°05.5W	4296	
28464	CTD 62	25 Oct	1315	32°19.5N	64°02.5W	4397	
28465	CTD 63	25 Oct	1714	32°04.6N	64°06.7W	4428	
28466	XBT 53	25 Oct	1920	32°02.2N	64°09.9W	4383	
28467	XBT 54	25 Oct	1950	31°58.9N	64°12.3W	4428	
28468	XBT 55	25 Oct	2018	31°55.5N	64°14.8W	4438	
28469	CTD 64	25 Oct	2045	31°52.1N	64°17.2W	4407	
28470	CTD 65	26 Oct	0044	31°43.8N	64°33.2W	4377	
28471	CTD 66	26 Oct	0427	31°41.3N	64°51.5W	4402	
28472	CTD 67	26 Oct	0744	31°45.3N	65°09.8W	4583	
28473	CTD 68	26 Oct	1153	31°54.8N	65°24.4W	4872	
28474	GEK 4	26 Oct	1345	31°55.3N	65°24.7W	4892	Around Bermuda - thru XBT 96
28475	XBT 56	26 Oct	1450	31°58.4N	65°20.4W	4020	
28476	XBT 57	26 Oct	1536	32°02.2N	65°16.2W	2555	
28477	XBT 58	26 Oct	1610	32°05.9N	65°20.0W	4739	
28478	XBT 59	26 Oct	1647	32°10.6N	65°22.5W	4771	
28479	XBT 60	26 Oct	1729	32°14.3N	65°26.8W	4732	
28480	XBT 61	26 Oct	1810	32°18.8N	65°29.7W	4771	
28481	XBT 62	26 Oct	1854	32°15.9N	65°23.9W	4802	
28482	XBT 63	26 Oct	1939	32°12.6N	65°18.5W	4634	
28483	XBT 64	26 Oct	2021	32°09.8N	65°13.5W	4132	
28484	XBT 65	26 Oct	2101	32°12.9N	65°08.1W	3077	NG >150 m
28485	XBT 66	26 Oct	2138	32°15.0N	65°04.0W	1214	
28486	XBT 67	26 Oct	1809	32°18.1N	65°03.1W	864	
28487	XBT 68	26 Oct	2232	32°21.1N	65°06.0W	2374	

Table IV - RV/EASTWARD 12-75 SCIENTIFIC EVENTS

Consec. Obs.#	Inst. Obs.#	Date	Start Time (GMT)	Launch Position Lat.	Long.	Bottom Depth Cor Meters	Comments/Quality
28488	XBT 69	26 Oct	2309	32°24.4N	65°09.0W	3271	
28489	XBT 70	26 Oct	2340	32°27.4N	65°05.8W	3293	
28490	XBT 71	27 Oct	0010	32°24.2N	65°02.0W	2102	
28491	XBT 72	27 Oct	0044	32°22.3N	64°58.6W	623	NG
28492	XBT 73	27 Oct	0110	32°25.0N	64°55.8W	904	
28492 A	XBT 74	27 Oct	0130	32°27.1N	64°58.4W	1754	
28493	XBT 75	27 Oct	0212	32°31.3N	64°59.6W	3363	
28494	XBT 76	27 Oct	0307	32°30.8N	64°54.0W	1404	
28495	XBT 77	27 Oct	0343	32°30.0N	64°49.2W	743	"SLO"; DEEP?
28495 A	XBT 78	27 Oct	0402	32°33.0N	64°49.9W	1953	
28496	XBT 79	27 Oct	0450	32°37.2N	64°46.9W	2857	DEEP?
28497	XBT 80	27 Oct	0531	32°33.7N	64°44.0W	1604	
28498	XBT 81	27 Oct	0601	32°31.9N	64°41.3W	704	
28499	XBT 82	27 Oct	0627	32°35.2N	64°38.8W	2122	
28500	XBT 83	27 Oct	0714	32°36.8N	64°33.2W	2686	
28501	XBT 84	27 Oct	0805	32°32.5N	64°33.8W	1544	
28502	XBT 85	27 Oct	0842	32°28.8N	64°34.9W	602	"SLO"; NG
28503	XBT 86	27 Oct	0912	32°29.3 N	64°30.2W	1834	
28504	XBT 87	27 Oct	1005	32°26.5N	64°24.9W	2947	
28505	XBT 88	27 Oct	1135	32°22.9N	64°34.6W	603	"SLO"; NG
28506	XBT 89	27 Oct	1211	32°19.0N	64°32.3W	1344	
28507	XBT 90	27 Oct	1302	32°15.0N	64°30.7W	2510	
28508	XBT 91	27 Oct	1441	32°16.6N	64°43.6W	653	"SLO"
28509	XBT 92	27 Oct	1510	32°13.7N	64°40.7W	1854	
28510	XBT 93	27 Oct	1550	32°09.2N	64°40.0W	2555	
28511	XBT 94	27 Oct	1710	32°12.9N	64°49.2W	643	"SLO"; NG >70 m
28512	XBT 95	27 Oct	1738	32°08.9N	64°48.2W	2263	
28513	XBT 96	27 Oct	1829	32°04.4N	64°50.9W	3127	NG >480
28514	XBT 97	27 Oct	1940	32°11.0N	64°56.0W	754	"SLO"; DEEP?
28515	XBT 98	27 Oct	2014	32°09.8N	64°59.6W	904	"SLO"
28516	CTD 69	27 Oct	2336	32°16.9N	64°37.7W	1009	Press. Acting Up
28517	CTD 70	28 Oct	0136	32°16.0N	64°36.0W	1982	
28518	CTD 71	28 Oct	0617	32°18.0N	64°32.0W	1654	
28519	CTD 72	28 Oct	0740	32°20.8N	64°28.1W	2202	
28520	CTD 73	28 Oct	0936	32°24.0N	64°28.0W	2072	

Table IV - RV/EASTWARD 12-75 SCIENTIFIC EVENTS

Consec. Obs.#	Inst. Obs.#	Date	Start Time (GMT)	Launch Position Lat.	Launch Position Long.	Bottom Depth Cor Meters	Comments/Quality
28521	SF 14	30 Oct	1730	32°23.0N	65°01.0W	1454	
28522	CTD 74	30 Oct	2202	32°23.7N	65°01.8W	1923	
28523	CTD 75	30 Oct	2345	32°22.2N	65°00.2W	964	
28524	XBT 99	31 Oct	0044	32°21.0N	64°59.1W	422	"SLO"
28525	XBT 100	31 Oct	0130	32°20.5N	65°00.6W	482	"SLO"
28526	CTD 76	31 Oct	0145	32°20.9N	65°01.4W	1154	
28527	CTD 77	31 Oct	0309	32°22.2N	65°02.9W	2122	
28527A	CTD 78	31 Oct	0539	32°21.0N	65°06.5W	2002	
28528	CTD 79	31 Oct	0743	32°19.5N	65°02.2W	1004	
28529	SF 1	31 Oct	1220	32°25.1N	65°06.5W	2857	
28530	SF 12	31 Oct	1355	32°21.2N	65°01.0W	1054	
28531	SF 17	31 Oct	1443	32°21.2N	65°04.7W	2404	
28532	SF 16	1 Nov	0026	32°24.0N	64°58.5W	1254	
28533	CTD 80	1 Nov	1211	32°12.0N	65°19.0W	4686	
28534	CTD 81	1 Nov	1538	32°22.5N	65°21.0W	4634	
28535	CTD 82	1 Nov	1928	32°32.9N	65°17.0W	4644	
28536	CTD 83	2 Nov	0457	32°42.0N	65°09.9W	4634	
28537	CTD 84	2 Nov	0811	32°46.9N	65°00.0W	4428	
28538	CTD 85	2 Nov	1118	32°48.5N	64°47.0W	4070	
28539	CTD 86	2 Nov	1730	32°46.0N	64°35.0W	1804	
28540	CTD 87	2 Nov	2030	32°40.0N	64°25.0W	3513	
28541	CTD 88	3 Nov	0013	32°31.0N	64°19.0W	3633	
28542	CTD 89	3 Nov	1628	32°20.0N	64°19.5W	3493	
28543	CTD 90	3 Nov	1758	32°20.0N	64°19.5W	3513	
28544	CTD 91	3 Nov	2036	32°10.0N	64°20.5W	3959	
28545	XBT-GV1	3 Nov	2107	32°10.0N	64°20.5W	3959	
28546	XBT-GV2	3 Nov	2111	32°10.0N	64°20.5W	3959	
28547	XBT-GV3	3 Nov	2115	32°10.0N	64°20.5W	3959	
28548	XBT-GV4	3 Nov	2120	32°10.0N	64°20.5W	3959	
28549	XBT-GV5	3 Nov	2125	32°10.0N	64°20.5W	3959	
28550	XBT-GV6	3 Nov	2130	32°10.0N	64°20.5W	3959	
28551	XBT-GV7	3 Nov	2135	32°10.0N	64°20.5W	3959	
28552	XBT-GV8	3 Nov	2139	32°10.0N	64°20.5W	3959	
28553	XBT-GV9	3 Nov	2143	32°10.0N	64°20.5W	3959	
28554	XBT-GV10	3 Nov	2147	32°10.0N	64°20.5W	3959	
28555	XBT-GV11	3 Nov	2150	32°10.0N	64°20.5W	3959	

Table IV - RV/EASTWARD 12-75 SCIENTIFIC EVENTS

Consec. Obs.#	Inst. Obs.#	Date	Start Time (GMT)	Launch Position Lat.	Launch Position Long.	Bottom Depth Cor Meters	Comments/Quality
28556	XBT-GV12	3 Nov	2154	32°10.0N	64°20.5W	3959	
28557	CTD 92	3 Nov	2318	32°02.0N	64°28.0W	3765	
28558	CTD 93	4 Nov	1402	32°03.5N	65°13.5W	1654	
28559	CTD 94	4 Nov	1626	31°57.0N	65°03.0W	3463	
28560	CTD 95	4 Nov	1915	31°55.5N	64°51.0W	4020	
28561	CTD 96	4 Nov	2206	31°56.4N	64°39.0W	4101	
28561A	XBT 101	5 Nov	0853	32°15.8N	65°03.8W	904	"SLO"; NG >300 m
28562	XBT 102	5 Nov	0940	32°10.2N	65°00.6W	954	"SLO"; NG >300 m
28563	XBT 103	5 Nov	1010	32°10.8N	64°55.4W	1004	"SLO"; NG >300 m
28564	XBT 104	5 Nov	1042	32°11.9N	64°50.5W	784	"SLO"; NG >300 m
28565	XBT 105	5 Nov	1113	32°13.9N	64°46.2W	884	"SLO"; NG >300 m
28566	XBT 106	5 Nov	1140	32°15.8N	64°42.2W	1134	"SLO"
28567	XBT 107	5 Nov	1210	32°18.0N	64°38.4W	879	"SLO"; NG >260 m
28568	XBT 108	5 Nov	1824	32°18.2N	64°36.0W	954	NG
28569A	GEK 5	5 Nov	1841	32°17.0N	64°37.2W	1029	Thru XBT 132
28569	XBT 109	5 Nov	1903	32°16.0N	64°40.2W	1154	"SLO"
28570	XBT 110	5 Nov	1930	32°13.8N	64°44.5W	1354	
28571	XBT 111	5 Nov	2000	32°12.0N	64°49.0W	904	"SLO"
28572	XBT 112	5 Nov	2030	32°10.8N	64°53.5W	1059	
28573	XBT 113	5 Nov	2101	32°10.2N	64°58.8W	663	"SLO"
28574	XBT 114	5 Nov	2130	32°11.2N	65°05.0W	2002	NG >310 m
28575	XBT 115	5 Nov	2200	32°12.0N	65°10.0W	2967	"SLO"
28576	XBT 116	5 Nov	2300	32°13.4N	65°19.2W	4065	
28577	XBT 117	6 Nov	0300	32°19.8N	65°53.5W	4782	
28578	XBT 118	6 Nov	0700	32°27.0N	66°27.0W	4852	
28579	XBT 119	6 Nov	1100	32°34.9N	67°05.1W	5012	
28580	XBT 120	6 Nov	1500	32°43.7N	67°46.0W	5122	NG
28581	XBT 121	6 Nov	1900	32°50.0N	68°26.0W	5167	
28582	XBT 122A	6 Nov	2310	32°58.5N	69°09.0W	5328	
28583	XBT 123	7 Nov	0300	33°10.5N	69°51.0W	5409	
28584	XBT 124	7 Nov	0700	33°16.5N	70°34.0W	5409	
28585	XBT 125	7 Nov	1100	33°24.6N	71°13.0W	5389	
28586	XBT 126	7 Nov	1500	33°34.0N	71°53.1W	5308	

Table IV - RV/EASTWARD 12-75 SCIENTIFIC EVENTS

Consec. Obs.#	Inst. Obs.#	Date	Start Time (GMT)	Launch Position Lat.	Launch Position Long.	Bottom Depth Cor Meters	Comments/Quality
28587	XBT 127	7 Nov	1900	33°43.1N	72°39.4W	4865	
28588	XBT 128	7 Nov	2300	33°52.7N	73°26.0W	----	
28589	XBT 129	8 Nov	0300	34°00.0N	74°10.9W	4193	
28590	XBT 130	8 Nov	0700	34°08.0N	74°47.0W	3573	
28591	XBT 131	8 Nov	1100	34°14.5N	75°20.5W	3007	NG >370 m
28592	XBT 132	8 Nov	1400	34°18.6N	75°44.5W	804	NG >440 m

D. Moored Array

In order to place the field experiment in proper perspective three moorings were deployed in a triangular array with Bermuda at the center. We anticipated that the low frequency or "mean" flow that would be present at the island would be the result of mesoscale eddy activity. The one month duration of the field work is comparable to periods of these eddies. The three moorings yield information on the relation between the essentially instantaneous eddy activity observed during the field work and long term averages for the area.

Moorings were set in May 1975 at positions indicated in Fig. 6 and recovered in January 1976. Common current meter depths were chosen to be 300 m, 500 m, 1000 m, and 1500 m (nominal). Temperature-pressure instruments from MIT were set at 750 m to monitor mooring motion. Additional current meters were placed at 720 m and 4000 m on mooring 555 (for Mel Briscoe and Bill Schmitz, respectively). A summary of instrument depths, types and performances is given in Table V.

Several problems arose which resulted in less than average data return. The 850 style current meters were set at a common 1500 m level and all developed deposition/corrosion problems which eventually led to stuck vanes and rotors. (The 4000 m instrument on 555 worked fine for some reason.) We used three VACM's modified to measure temperature difference over 1.7 m. In order to get 9 month exposure--this configuration has increased current drain--a new lithium oxide battery was employed. These batteries degassed, producing vapors which attacked the electronics, tape recorders and magnetic tape. The temperature depth recorder on 555 was apparently damaged on launch, and the one on 554 had an electronics failure; the 553 instrument worked fine. All VACM's functioned perfectly.

Temperatures and current vectors at the 300 m level for all three moorings are shown in Fig. 7. These have been low pass filtered to remove energy shorter than 24 hour periods and the duration of the field experiment is shown by the vertical lines. This period is in a transition between dominance by a large Gulf Stream ring to the north early in the period and a smaller ring to the south towards the experiment's end.

Table V

BERMUDA MOORINGS SUMMARY INFORMATION

Mooring Position	Inst. No.	Inst. Type	Depth (m)	Data Length	Comments
533	5531	VACM	306	28/4/75 - 27/1/76	
31°46.9 N	5532	DT-VACM	506	28/4/75 - 17/10/76	- battery problem
64°26.2 W	5533	T/D	725	30/4/75 - 27/1/76	
	5534	VACM	1005	28/4/75 - 27/1/76	
	5535	850	1505	28/4/75 - 27/1/76	- vane stuck after 3/9/76
					- rotor " " 19/12/76
554	5541	VACM	314	29/4/75 - 26/1/76	
32°21.5 N	5542	VACM	514	29/4/75 - 26/1/76	
65°27.0 W	5543	T/D	733	30/4/75 - 30/8/76	- incomplete
	5544	VACM	1013	29/4/75 - 26/1/76	
	5545	850	1513	29/4/75 - 26/1/76	- vane stuck after 26/5/76
					- rotor " " 19/10/76
555	5551	VACM	316	29/4/75 - 25/1/76	
32°59.0 N	5552	DT-VACM	516	29/4/75 - 12/8/75	- battery problem
64°23.8 W	5553	T/D	736	30/4/75 - 20/5/75	- incomplete
	5554	DT-VACM	766	29/4/75 - 21/11/75	- battery problem
	5555	VACM	1016	29/4/75 - 25/1/76	
	5556	850	1516	29/4/75 - 25/1/76	- vane stuck after 12/6/75
	5557	850	4016	29/4/75 - 25/1/76	

VACM = Vector averaging current meter
DT-VACM = VACM modified to measure temperature difference over 1.7 m
850 = Geodyne 850 style current meter
T/D = M.I.T. temperature-pressure recorder

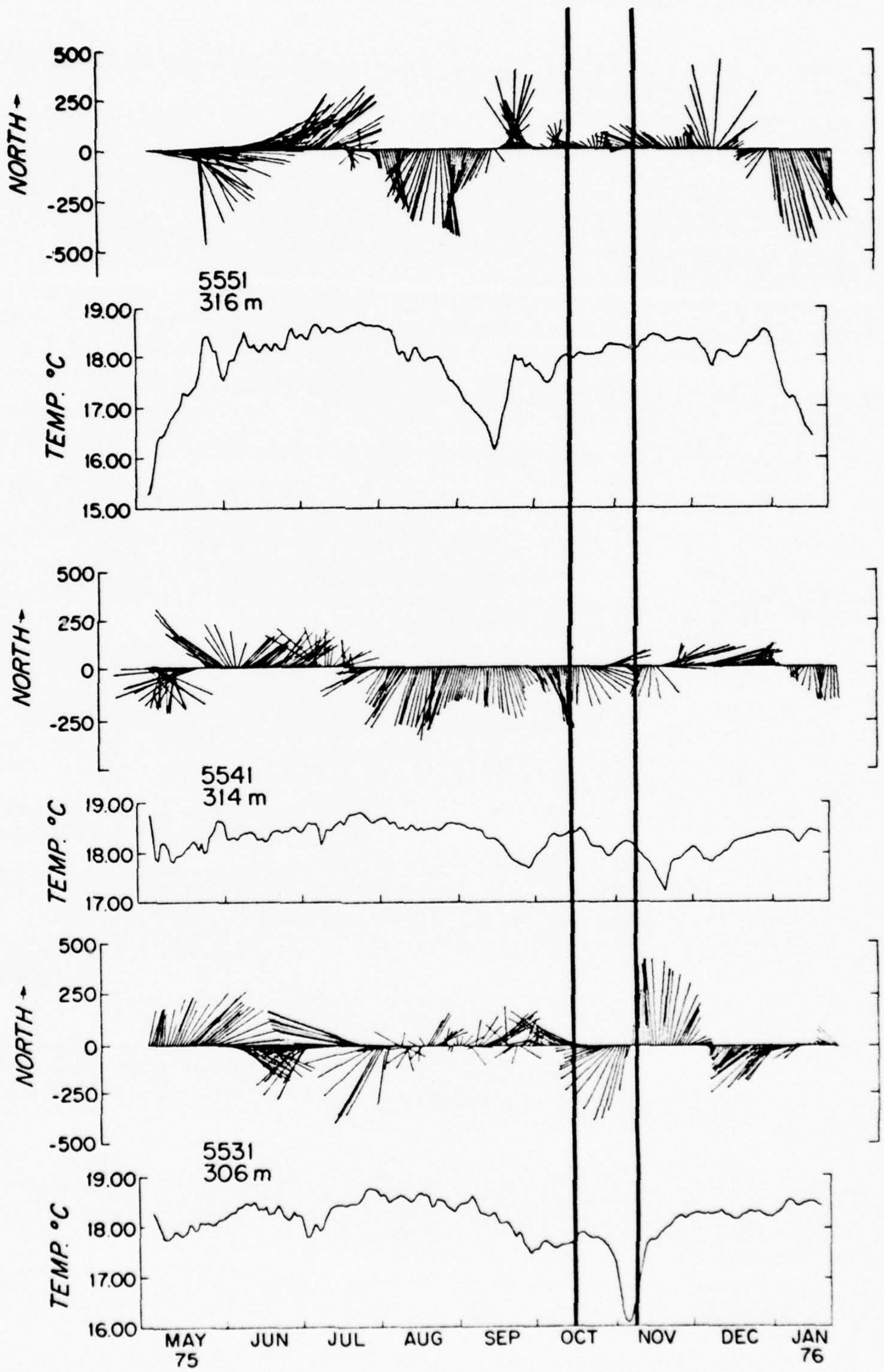

Fig. 7. Low-passed time series of current and temperature at 300 m depth from moorings 553, 554, and 555. Duration of near Bermuda field work is between the two vertical lines

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APPENDIX

Description of Measuring Systems and Performance Specifications

Name of Instrument: The Electro-Magnetic Velocity Profiler (EMVP)

By: T. Sanford, R. Drever

a) Purpose of measurement system:

The free-fall Electro-Magnetic Velocity Profiler (EMVP) (Figure 1) measures and records weak electric currents produced by the motion of the sea through the geomagnetic field. The electric current measurements as a function of depth are interpreted in terms of the depth variable, horizontal velocity field. A complete velocity profile in 6000 meters of water is achieved in about 1-1/2 hours with an uncertainty of about 1 cm/s at a vertical resolution of 10 meters. In addition to velocity, temperature, electrical conductivity, pressure, magnetic field, internal temperature and external r.m.s. temperature gradient are recorded twice per second internally on a digital cassette recorder.

b) Description of primary measurement and principles of operation:

The motionally induced electric fields are sensed by two pairs of horizontally-spaced electrodes mounted on a freely-falling, rotating probe. The Ag-AgCl electrodes are individually housed in electrically insulating electrode blocks. Salt bridges made of vinyl tubing connect the electrodes to the skin of the instrument where the electric field is sensed at a spacing of 37 cm.

The direction of the electric field is measured by comparing the phase of the electric field signal with a signal generated by a compass coil. The compass coil is made from many turns of wire wound on a high permeability core. The coil is aligned perpendicular to the axis of the instrument. As this coil rotates in the horizontal component of the earth's magnetic field, a sinusoidal voltage is induced with phase referenced to the angle between the coil axis and magnetic north. The amplitude and phase of the electrode voltage relative to the compass coil is used to determine the electric field vector. The electric field vector is converted to the equivalent horizontal velocity vector.

Temperature is sensed with a platinum resistance temperature element, Model 171BJ, made by Rosemount Engineering Company.

Pressure is sensed with a bonded strain-gage transducer, part number 211-35-090-05, made by Standard Controls, Inc.

Conductivity is sensed by two toroidal transformers housed in a pressure protected insulated case. The sensor is Model 2600-3 made by Plessey Environmental Systems, Inc.

Internal temperature and r.m.s. temperature gradient are sensed by thermistors.

The magnetic field is sensed by a 3-axis, flux gate magnetometer (model 9200, Develco, Inc.).

c) Performance specifications for sensors:

Pressure transducer Model 211-35-090-05, Standard Controls, Inc.

1) Range - 0 to 8850 psi (6102 dbar)
2) Non-linearity and hysteresis combined - .07% of full scale (best straight line method) ±4.3 dbar
3) Repeatability ±.05% of full scale: ±3 dbars
4) Zero balance ±2.0% of full scale: ±122 dbars
5) Compensated temperature range -2° to 40° C
6) Thermal zero drift less than .0099% of full scale/°C: .60 dbar/°C or 18 dbar/30°C
7) Thermal sensitivity drift less than .0099% of full scale/°C: .60 dbar/°C (18 dbar/30°C)
8) Sensitivity 2.5 mv/volt ±10%

Platinum Resistance Temperature Sensor

Model 171BJ made by Rosemount Engineering

1) Temperature range - -2°C to 35°C
2) Resistances at 20°C - 100 Ω
3) Sensitivity - .365 Ω/°C
4) Self-heating - In 20°C water flowing at 3 ft/sec transverse to sensor, the self-heating error (I^2R) shall be less than +0.005°C per milliamp excitation current
5) Repeatability - The sensor shall withstand 10 shocks between -2°C and +35°C without shifting calibration more than 0.01°C
6) Stability - better than 0.01°C for one year when operated in the range of -2°C to +35°C under normal conditions.

Conductivity Head

Model 2600-3 made by Plessey Environmental Systems

1) Range - 10 to 60 mmho/cm
2) Accuracy - ±0.03 mmho/cm
3) Repeatability - ±0.02 mmho/cm
4) Time constant - 0.10 seconds

The Ag-AgCl electrodes and electrode assemblies are made at the Woods Hole Oceanographic Institution.

Digital to Analog Converter (WHOI built)

Input analog range - 0 to -5 volts DC

Number of bit - 12 bits binary

Digital range - 0 to 4096

Temperature stability - ±30 ppm/°C ≃ ±0.1%/30°C.

d) Description of data acquisition system, data recorder and storage format:

The data acquisition system in EMVP (Figure 2) consists of a 16-channel analog multiplexer, a 12-bit analog to digital converter, and a 11.5 million-bit digital magnetic cassette tape recorder. The analog channels are digitized once every half second. The conversion time is 0.5 milliseconds per channel giving a total of 8 millisec for all 16 channels. The data is temporarily stored in a 192 bit serial shift register. Four bits at a time are then recorded on the cassette recorder at a rate of four bits every ten milliseconds. The format of the data on tape is twelve 12-bit words; electric field 1, electric field 2, compass coil, pressure, temperature, conductivity, expanded pressure, expanded temperature, expanded conductivity, three magnetic field words, internal temperature, r.m.s. temperature; one 6-bit word for tape identification; and one 18-bit word of elapsed time with a resolution of 1/2 second.

e) Description of vehicle or package:

The EMVP vehicle consists of a 7.3-inch diameter and .75-inch wall thickness 7075-T6 anodized aluminum pressure cylinder, 5 feet in length ending with hemispherical end caps. The pressure case is designed to withstand 9,000 psi (6000 m depth). The forward half of the cylinder is surrounded by 5 collars of buoyant syntactic foam. Covering the foam and cylinder is a 14-inch diameter cylindrical shell or skin of medium density polyethylene. Attached to each end of the pressure cylinder are cages made of aluminum tubing sealed so as to provide buoyancy. Near the center of the skin are four holes connected by hollow plastic tubes to the two pairs of electrodes. The electrodes sense the potential along the line connecting diametrically opposed holes and the surrounding sea water. Mounted on the forward end, within a cage, are the pressure, temperature, and electrical conductivity sensors. A radio unit and a Xenon flasher are mounted on the top of the cage on the forward end of the instrument. At the opposite end, a collar is mounted holding 8 pitched fins to rotate the probe as it falls through the water. On the hemispherical end cap is mounted a 5 kHz acoustical projector used for acoustic tracking of the probe.

On deck, the vehicle is carried on a special cart and can be secured on the main deck. It is convenient to wheel the cart into the main lab before and after drop (see Item j).

f) Description of radio and acoustical emissions:

1. Acoustic emissions

a) EMVP

1) Low-frequency: At 5.0, 6.0, or 7.0 kHz a series of pulses of 5-15 msec in duration emitted several times per second. One pulse is synchronous with an internal precision clock (used to determine EMVP-vessel slant range) while the other pulses are data telemetry pulses and are emitted asynchronously. The peak power is about 10 watts acoustic (i.e., power into the water). We can operate with much interference since we do not rely on data transmission by this method. Any of the three frequencies (±100 Hz) are usable and may be monitored from our equipment on the ship.

b) Fathometer

Using our Gifft PGR we operate a 12 kHz at various pulse durations and repetition rates. Several hundred watts acoustic are emitted.

2. RF emissions

OAR submersible transmitters (Model ST-206-100S-LP) producing about 100 milliwatts on 4 channels are used:

Frequency (mHz)	CB Channel
26.995	A
27.045	B
27.095	C
27.145	D

The emission is CW with AM-FSK modulation producing a two-tone, warble sound when demodulated.

g) Description of data processing procedures:

The raw data sequence consists of twice-per-second measurements of two electric field values, compass or orientation, pressure, temperature, electrical conductivity and time. A set of 15 of each of the recorded values are examined and tested against certain statistical requirements. Measurements which deviate from the statistical norm too far are rejected and removed from the data set. Then the edited set, provided that more than 2/3 of the original set remains, is fitted by a least-square method to appropriate functions. For the electric fields and compass the fitting functions consist of a mean, trend and sinusoid, while pressure, temperature and conductivity are fitted to a mean and trend. All fitting windows

are 7.5 seconds except for pressure which is 20 seconds (occasionally 40 seconds) long. Also the standard deviations of the difference between the edited data and the fit are computed as a measure of data quality. Next, the fitted functions are evaluated in terms of velocity, pressure, temperature and conductivity. These values are then an average over 7.5 seconds or 7-8 dbar, depending on fall rate. Then the whole process is repeated, but with the "windows" moved 7.5 seconds along the sequence. This sequence continues until the profile has been completely processed. A listing and output tape of the profile are generated.

Since the fit is done over equal time blocks, the depth scale is not equally spaced. A further step in the processing linearly interpolates (2 point interpolation) the profile data onto an equal depth interval scale of 10 dbar increments.

The routine processing yields profile data every 10 dbar with values completely independent about every 7-8 dbar.

h) Calibration procedures and reference standards:

The pressure channel was calibrated on American Instrument Co., Inc. dead-weight tester Model #47-2221, serial number F966. The weights for the tester were calibrated by the Commonwealth of Massachusetts Executive Office of Consumer Affairs, Division of Standards, on May 17, 1972.

The temperature and conductivity sensors and associated electronics were calibrated at the same time in a bath large enough to allow the submergence of the front half of the instrument. The temperature of the bath was measured using a model 2801A Hewlett-Packard quartz thermometer (electronics S/N 602-00339) and probe model 2580C (S/N 979-25). The quartz thermometer was calibrated with a Leeds and Northrup Mueller bridge model 8069B (S/N 1696581) and a Leeds and Northrup platinum probe (having characteristics traceable to the National Bureau of Standards). A Transonic Equiphase triple point of water cell, type 130, (S/N 42273) was used to check the Mueller bridge and platinum probe system.

The conductivity was checked by taking samples of the bath water. These samples were measured with an Auto-Lab inductive salinometer #77 using P_{60} Copenhagen water.

The electric field channels of the instrument were calibrated by electrically measuring the phase and amplitude response of the electric field amplifiers and filters. The spacing of the electrode ports on the skin were measured with calipers and scale.

i) Performance of measuring system:

1. Expected performance

Velocity: within 1 cm/s as compared with Swallow floats and Pochapsky profiles (see references) within 0.5 cm/s between 2 EMVPs deployed simultaneously at separations <100 m.

Pressure: within 1.25 dbar for repeatability comparison with PGR records of water depth. Mid-depth uncertainties are as large as 20 dbar, a value which can be reduced to ±5 dbar.

Temperature: within 0.01° C by comparison with simultaneous CTD profile.

Conductivity: within 0.04 mmho/cm below 500 dbar by comparison with simultaneous CTD profile and lab calibrations before and after cruise.

2. Future performance

Velocity: improved near-surface performance is possible with redesigned electrode system. Less noisy amplifiers might improve the velocity measurements somewhat. We do not know how much of the noise in the measurement is due to electronics and how much is inherent in the ocean.

Conductivity: the conductivity sensor is now filled with castor oil which will permit pressure compensation to 6000 dbar.

j) Description of deployment or sea operations:

Prior to launch, a short section of the electronic rack is unplugged from the probe and brought into the lab. The recorder is cleaned and a new cassette tape is inserted. A freshly charged battery is installed and the precision clock is synchronized with a master clock in the lab. Thumb-wheel switches are set to identify the drop and instrument numbers and to determine the amount of time delay until the probe releases a surface float and starts to fall. The short section of electronics is then inserted into the vehicle and attached with a V-channel clamp. The surface release solenoid is test-fired, then plugged in with a balloon attached to the release mechanism. The radio beacon and Xenon flasher unit is installed on the forward cage. A set of lead ballast weights weighing 30 lb are made up and set aside near the launch station.

When ready to be launched, the instrument is raised, using a quick-release hook, by the projector cage while the forward cage is lifted and guided manually. Once vertical, the instrument is swung over the rail, steadied by hand, ready for attachments of weights. After the weights are attached, the instrument is lowered into the water. The behavior of the instrument is closely watched to detect any problems such as leaking and a check is made of the acoustic signals received via the shipboard hydrophone. When all appears to be ready, the looped retaining line is released and brought aboard. The ship gets underway to remove its electric field from the vicinity of the now-free instrument. The instrument is tracked acoustically by using either hull-mounted hydrophones or a pair of phones on a cable put over the side. If not engaged in other work, the ship stands off several hundred meters until the surface float is released.

While the instrument is profiling, the depth and slant range are monitored and displayed on a 19-inch Gifft precision graphic recorder. Occasionally the horizontal range is calculated. At some point, depending on other commitments, the ship gets underway and returns to the vicinity of the launch point. Usually, the return is guided by the real-time analysis of the range information. Also the ship can be guided by the radio direction finder using the radio beacon signal. At night the Xenon flasher is quite effective in moderate seas. At night a strong hand-held spotlight is directed on the instrument at all times.

As the ship maneuvers for an approach into the wind (and sea), long aluminum poles supporting hooks attached to light lines are manned. As the instrument passes alongside, the poles are maneuvered so that a hook catches on one of the bars of the forward guard cage. As the pole is withdrawn, the hook remains and a safety bar is released to close the bail. The hook is now securely attached allowing the instrument to be slowly pulled alongside. The instrument can be raised by the snap hook and its line or another rig can be used now.

k) References:

Sanford, T. B., R. G. Drever, and J. H. Dunlap, "The design and performance of a free-fall electro-magnetic velocity profiler (EMVP)." W.H.O.I. Technical Report 74-46 (unpublished manuscript), 114 p., July 1974.

Sanford, T. B., 1975. "Observation of the vertical structure of internal waves." J. Geophys. Res. 80, 3861-3871.

Leaman, K. D. and T. B. Sanford, 1975. "Vertical energy propagation of inertial waves: a vector spectral analysis of velocity profiles." J. Geophys. Res. 80, 1975-1978.

Leaman, K. D., 1976. "Observations on the vertical polarization and energy flux of near-inertial waves." J. Phys. Oceanogr. 6, 894-908.

Rossby, H. T. and T. B. Sanford, 1976. "A study of velocity profiles through the main thermocline." J. Phys. Oceanogr. 6, 766-774.

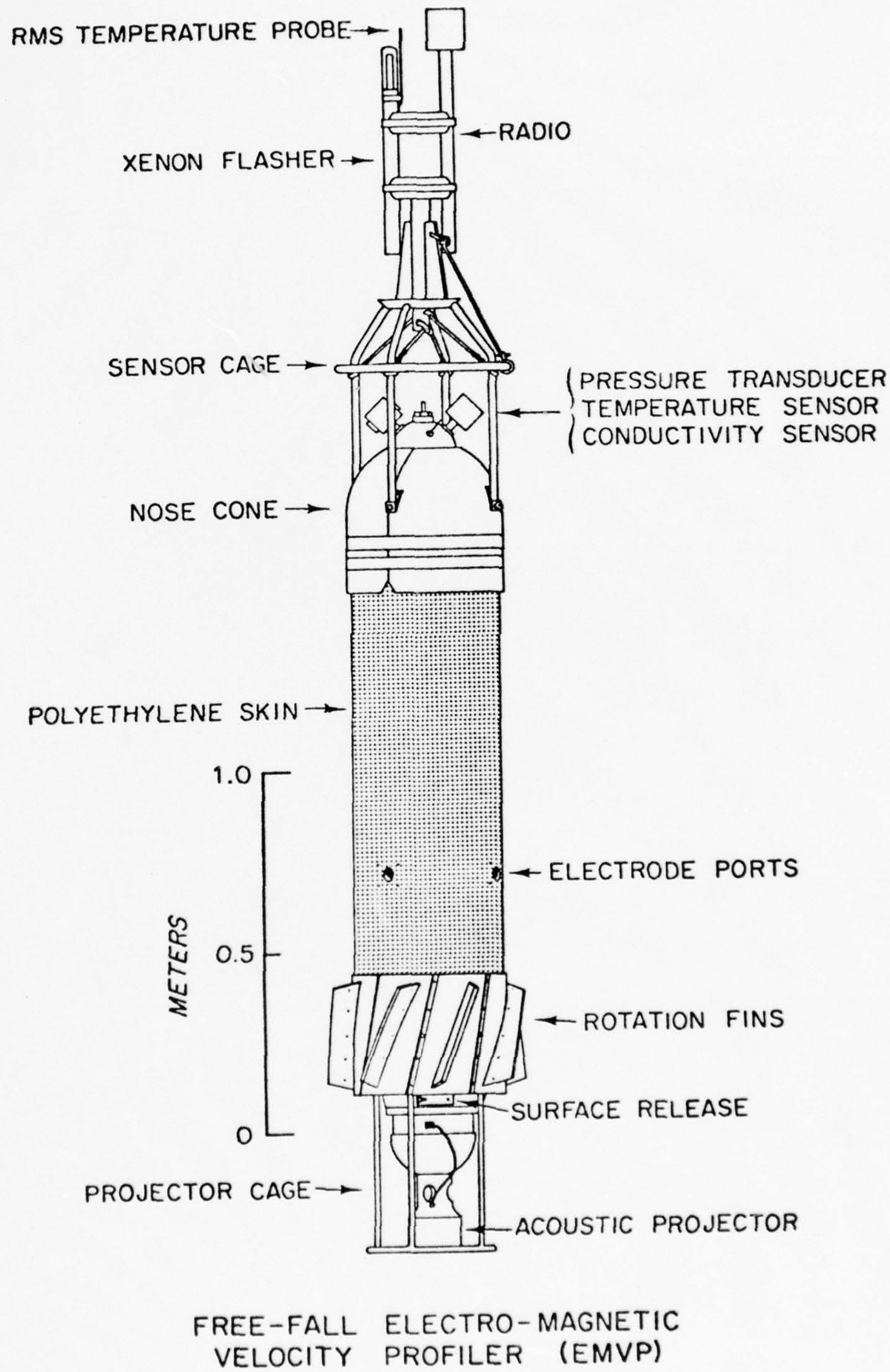

RMS TEMPERATURE PROBE
RADIO
XENON FLASHER
SENSOR CAGE
PRESSURE TRANSDUCER
TEMPERATURE SENSOR
CONDUCTIVITY SENSOR
NOSE CONE
POLYETHYLENE SKIN
1.0
ELECTRODE PORTS
METERS
0.5
ROTATION FINS
SURFACE RELEASE
0
PROJECTOR CAGE
ACOUSTIC PROJECTOR
FREE-FALL ELECTRO-MAGNETIC
VELOCITY PROFILER (EMVP)

Fig. A1. EMVP

Description of Measuring Systems and Performance Specifications

Name of Instrument: YVETTE

By: T. Rossby and D. Evans

a) Purpose of measurement system:

The shear profiler (YVETTE) (Figure 1) measures and records velocities (relative to the instrument), conductivity, and temperature as a function of pressure while falling freely at a nominal rate of 25 cm/sec. It was designed to measure the fine structure of vertical shear and density of the main thermocline (maximum operating depth $\sim$1500 m). The data plus a clock and compass are recorded digitally every 400 msec on a Sea-Data recorder.

b) Description of primary measurement and principles of operation:

The current measuring system consists of two orthogonal acoustic (*time-of-flight* difference) current meters built by Trygue Gytre of the C. Michelson Institute, Bergen, Norway, which have a precision of approximately 0.5 mm/s. They measure the difference in the time required for a signal propagate in each direction between two sensors separated by 31 cm. This difference is proportional to the velocity in the direction parallel to the line between the sensors.

Temperature, pressure and conductivity are measured by a Neil Brown CTD (without the fast temperature response sensor). There is also an eight bit digital compass designed by Donald Dorson.

c) Performance specifications for sensors:

Current meters: $\sim$0.5 mm/sec resolution.

There is an apparent temperature-induced drift which has no detectable effect at small (<50 m) scales for the relative measurements.

N. Brown CTD: resolutions of 0.001° C, 0.002‰ salinity, 0.1 dbar pressure.

d) Description of data acquisition system, data recorder and storage format:

The data are recorded on a Sea-Data digital cassette recorder.

Each record is 96 bits:

4×16 bits -- clock, pressure, temperature, cond.

1×8 bits -- compass

2×12 bits -- current meters.

e) Description of vehicle or package:

YVETTE consists of a 4 meter 6061-T6 aluminum pressure case with 7-1/2" diameter ending with hemispherical caps. The sensors are mounted below the bottom cap with CTD penetraters as shown in Figure 1. Not shown in Figure 1 are a protective cage around the sensors and a recovery ring mounted at the top of the tube. Also located at the top are a radio, flasher and 10 kHz pinger for recovery location. The vehicle must be stored on deck.

f) Description of radio and acoustical emissions:

1. Radio emissions: OAR radio for recovery at 29.995 mHz (CB channel A).
2. Acoustic emissions: 10 kHz pinger with a 10 msec pulse every 4 seconds at 80 db re 1 μbar.

g) Description of data processing procedures:

1. At sea: the cassette tape can be played back through a Sea-Data reader and "bit box" (used as a four channel D/A convecter) to a strip chart recorded. Two passes through the data provide sufficient information to detect instrument malfunction.

   With a Hewlett-Packard 2116 computer system the un-edited data can also be tabulated and plotted with calculation of standard parameters (Sigma-t, Richardson number, etc.).

2. Ashore: The raw data are converted to calibrated engineering units and are edited to remove "bad points" in two stages. First, badly out of range pressure (>1500 m) and raw relative velocities (>10 cm/s) are located, the points discarded, and a least square parabola is fit to the pressure data. Then, temperature, salinity, and velocity data are first differenced and points which differ by too large a value are removed. Since most of the errors occur in the recording system the location of a 5 dbar difference from the least square parabola and/or a point spike in T, C, U, or V identifies a bad data point effectively. The rejected points are examined and, in rare cases, may be hand corrected or reinserted.

   The edited series is then used to compute salinity, following a correction to the temperatures for the time constant mismatch between thermometer and conductivity sensors. A velocity profile is produced by rotating the current meter outputs into magnetic coordinates and integrating as follows: the currents are measured relative to the sinking and translating instrument; since the fall speed greatly exceeds the relative horizontal speed, the drag is effectively linearlized and localized to the leading end of the tube. For each time step, drag is computed for each element of tube length and a new value of the velocity of the tube is computed using the fact that the measured velocity is relative to the tube. The drag coefficient

and shape of the distribution were determined by comparing results with velocities measured by tracking YVETTE with bottom-mounted hydrophones.

The whole data series, T, S, U, and V are then smoothed with a Gaussian filter whose length depends upon the purpose of the calculation but is always at least three points (i.e., $\sigma \simeq 6$ cm). P, T, and S are then used to compute Brunt-Väisälä frequency and shear is obtained from P, U, and V. The entire series P, T, S, U, V, U_z, V_z, $S^2 = (U_z^2 + V_z^2)$, and N^2 is written out for further reference.

h) Calibration procedures and reference standards:

The CTD is calibrated at URI before each use. Temperature is calibrated against a Hewlett-Packard quartz thermometer and conductivity is calibrated using Copenhagen water. Pressure was last calibrated in October 1975 with a dead weight tester at Neil Brown Instruments.

The current meters are calibrated in a tow tank at URI.

i) Performance of measuring system:

Velocity: $\sim$0.5 mm/sec resolution
$\sim\pm5$ cm/sec for scales less than 100 m. Apparent temperature induced drift and uncertainty in the algorithm makes velocity of unknown quality for greater scale.

CTD: see section (c).

j) Description of deployment or sea operations:

Instrument lies horizontally on deck near suitable crane or cherry picker that can clear 7.5 meter long tube in the vertical. The tube is raised and lowered in vertical position into and out of water. The instrument free falls and drops 4 kg weight when either the pressure exceeds a certain value or time exceeds a preset value. Recovery uses standard acoustical maneuvering and/or radio, flasher contact. On an upwind approach, long poles are used to grab the upper end.

k) References:

None.

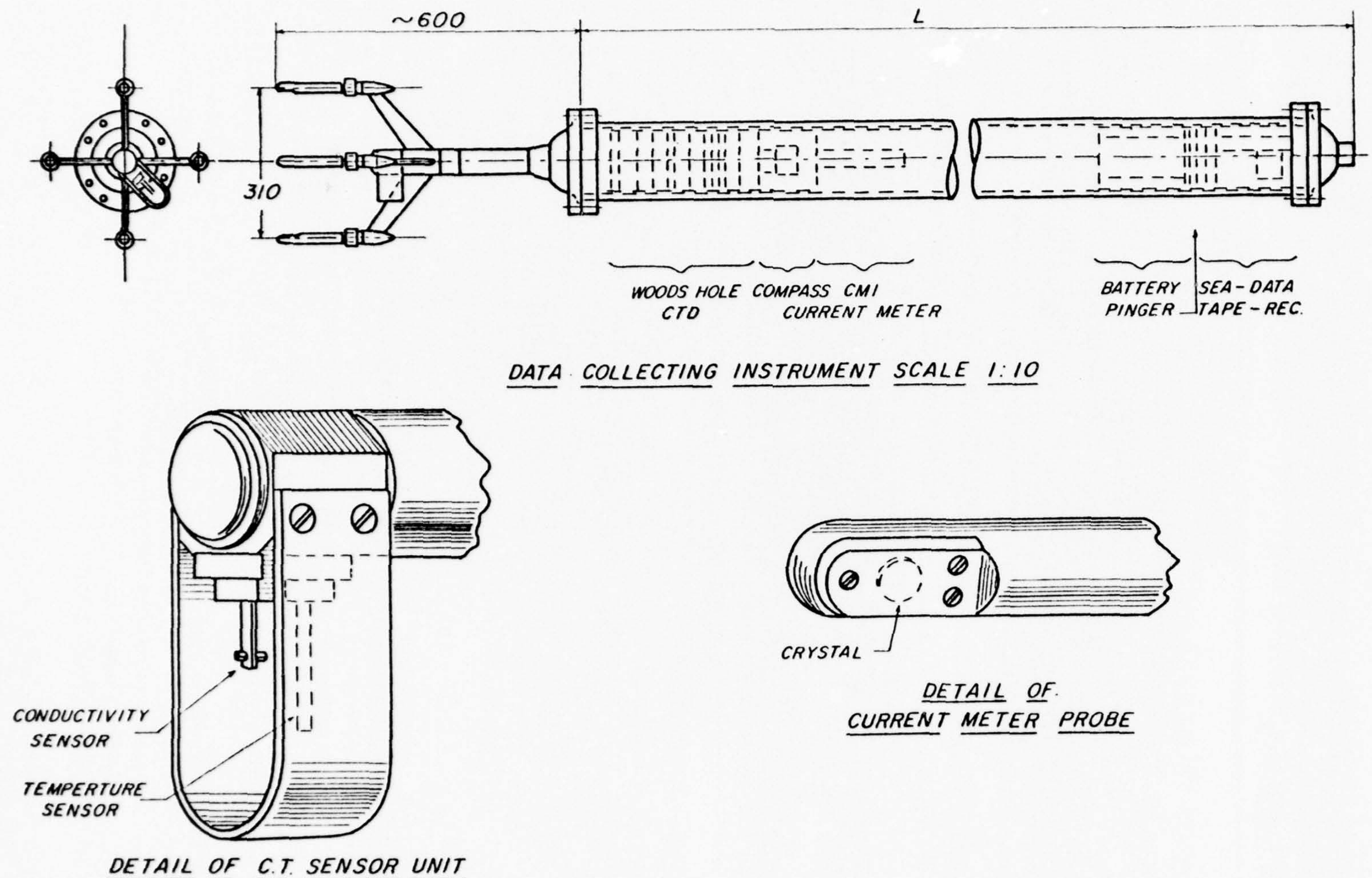


Fig. A2. YVETTE

Description of Measuring Systems and Performance Specifications

Name of Instrument: CAMEL

By: A. E. Gargett and T. R. Osborn

a) Purpose of measurement system:

CAMEL is a free-fall vehicle intended primarily for the measurement of oceanic shears in the dissipation range (roughly .5 m to a few centimeters), using the airfoil probe described by Osborn and Siddon (1973). Auxiliary measured variables are temperature, temperature gradient, conductivity, conductivity gradient, and pressure. Sensor voltages are converted to FM signals by voltage- controlled oscillators (VCOs) in the vehicle. The FM signals are transmitted to a support vessel through a Sippican expendable wire link and recorded on an FM tape recorder. Profiles are taken from the surface to a maximum depth of about 800 m. At a typical drop rate of 50 cm s^{-1}, such a profile takes about half an hour: since the instrument rises at a rate of about 1 m s^{-1} after release of its ballasting weights, the typical time from launch through recovery rarely exceeds an hour.

Figure 1 shows the configuration of the various sensors, recovery aids, etc. on the body.

b) Description of primary measurement and principles of operation:

Sensors:

Temperature:	Thermometrics BB05PB853N/A microbead thermistor, coated with paralene-C.
Temperature Gradient:	obtained by differentiating the thermistor signal; (-3 db point relative to derivative at 35 HZ).
Pressure:	1000 psi Vibrotron transducer located on the upper end cap of the instrument housing.
Conductivity:	modified Gregg-Cox salinometer, constructed at Institute of Oceanography, U.B.C. Limited travel of the piston which sucks water through the sensing port restricts this measurement of the first 300 m of each drop.
Conductivity Gradient:	obtain by differentiating the conductivity signal (-3 db at 20 HZ).

Shear: Vertical shears of two mutually orthogonal components of horizontal velocity are sensed by the airfoil probe described by Osborn and Siddon (1973). The technique employs a small axi-symmetric side force sensor which is exposed to an oncoming flow directed along the probe axis, provided in the present application by the uniform vertical fall speed $\overline{W}$ of CAMEL. The probe responds to waviness in the oncoming flow in much the same way that a phonograph pickup detects the "waviness" in a record groove. If a single spectral component of horizontal velocity is represented by a sinusoidal wave of vertical wavelength λ, the sensor experiences a modulated side force of this wavelength as it falls vertically. The side force results from a distribution of positive and negative pressures over the tip of the probe: for an axisymmetric body of revolution, the fluctuating pressure distribution is confined to a distance from the probe tip of $2 \rightarrow 3$ times the probe diameter. The side force is detected by making the probe nosepiece of a moderately flexible epoxy, in which are embedded one or more piezoceramic bimorph beams of the type commonly employed in phonograph cartridges: using two orthogonal bimorph elements, the two components of horizontal velocity, u and v, are converted to time varying voltages. These voltages are differentiated by the preamplifier and further high-pass filtered at 1 HZ to remove low-frequency effects due to temperature variation. Recorded voltages are thus proportional to the time rate of change of the two horizontal velocity components, and can be converted to vertical shears by dividing by the fall speed $\overline{W}$ of the body.

c) Performance specifications for sensors:

Thermistors: A Thermometrics special order bare bead .004"-.006', coated with paralene-C by Sippican. Nominal resistances 50 K ± 25% at 20°C with a coefficient of resistance (3.94 ± .02) %/C°.

Shear Probe: made at U.B.C. (see section i) for more information)

Salinometer: made at U.B.C. (see section i) for further information)

Pressure transducer (0-1000 p.s.i.) Vibrotron: for actual performance, see section i).

d) Description of data acquisition system, data recorder and storage format:

Within the pressure case, output voltages from the sensors are converted to FM signals using voltage-controlled oscillators: the vibrotron itself is an FM device. The FM signals are multiplexed and transmitted from the instrument to the support vessel along a Sippican Expandable Wire length, consisting of two spools of fine 2-conductor wire, one spool being attached to the instrument while the other remains attached to the support vessel: sea water is used as the signal return path.

On board ship, the FM signals are recorded directly on one channel of an HP 3960B tape recorder: a stable 14.5 kHz signal is recorded on a second channel to provide tape speed compensation on playback. During a profile, signals are decoded by a set of Sonex S-35 discriminators and displayed on a chart recorder in real time.

e) Description of vehicle or package:

The CAMEL is shown in Fig. 1. The pressure case is a 3 m long, 16 cm diameter aluminum tube with collapse depth around 1000 m. Temperature, conductivity, and shear sensors are mounted on the lower end of the tube, while the vibrotron pressure transducer is housed at the upper end of the tube, 4 m above the other sensors. The upper end also houses the OAR submersible radio and flashing light used as location aids. The instrument weighs approximately 150 lbs in air, is easily recovered with Williams's hook and a small crane, and must be stored and serviced within the lab.

f) Description of radio and optical emissions:

CAMEL uses OAR submersible transmitters and a hand-held receiver for daytime location, an OAR flashing light for night location.

g) Description of data processing procedures:

As remarked in section d), analog chart records of all signals are available in real time on board ship.

Subsequent digitization of the analog records is carried out at I.O.U.B.C., with:

Digitization rate: 200 HZ/channel low-pass filter cut-off frequencies:
shears, 60 HZ
temperature, 8 HZ

A/D conversion factor .004 V/digital unit (10 bit converters set up to give $\pm 2V = \pm 500$).

Digital chart records showing all measured variables as functions of depth are produced with 8-pt averages of the sampled data, an effective sample rate of 25 HZ.

Further plots are available of estimates of the energy dissipation rate ε, as obtained by direct integration of the spectra of the measured shears.

h) Calibration procedures and reference standards:

The Vibrotron pressure transducer is calibrated with an Amthor dead weight tester Model #452.

The thermistor is calibrated against a mercury and glass thermometer with an accuracy of ±.1 C°.

The shear probes are calibrated by being rotated at a known angle of attack in jet of known speed. The details of calibrator design, calibration and accuracy are described and discussed by Crawford (1976) which is available from the Institute of Oceanography, University of British Columbia, upon request.

The Salinometer head is calibrated to determine the equivalent cell resistance using water of known salinity (measured on an Auto-Lab Model #601 Mk III) and temperature. The calibration is performed with the water flowing through the nozzle at the same rate as in the ocean.

The voltage controlled oscillators and discriminators in the telemetry system are calibrated with a digital voltmeter (Fluke Model 8000A) and a counter (Hewlett Packard Model 523 CR). The appropriate manner to calibrate the thermistor, associated temperature circuit, and V.C.O. is as one package from a known temperature to a frequency. Unfortunately this was seldom done in the past.

i) Performance of measuring system:

1. Pressure: Calibrations over the period of a year and one-half ranging in temperature from 12 to 21° C show a difference in zero pressure frequency corresponding to about 5.3 m. The change in calibration value for 800 p.s.i. has changed by about two-thirds as much in the same direction. The final calibrations were after the vibrotron was over-ranged several times on the Bermuda Cruise. The temperature sensitivity as measured after the Bermuda Cruise between 12 and 20° C is less than .2m/C° at the surface and decreases with increasing pressure.

   The digitizing scheme will introduce an offset error of 1-2% of full scale (1000 p.s.i.). Hence an offset error in depth of 20 m is quite possible.

2. Temperature: An absolute accuracy of ±0.2 C° after calibration against an adjacent CTD. Precision to within ±0.05 C°.

3. Temperature Gradient: Limited by the spatial resolution of the probe which is - 3 db between 4 and 5 cm wavelength. See Lueck, et al. for a complete discussion of the thermister response.

4. Shear Probes: The r.m.s. noise level is about 8×10^{-3} sec^{-1}. The spatial resolution discussed by Crawford (1976).

j) Sea operations:

When ready for launch, CAMEL is carried onto the deck, and hoisted overboard with a small crane. When in launch position, with all sensors

submerged, a check of the incoming signals is obtained; the instrument is then freed by pulling a cable to the launcher. As one reel of the Sippican Expendable Wire length remains on the launcher (while the other descends with the instrument), the crane holding the launcher must remain outboard until completion of the drop; as soon as the instrument drops its ballast weights and begins to return to the surface, the crane may be brought inboard, the launcher removed, and preparations for recovery begun.

When the instrument is located on the surface (section f), the ship is maneuvered alongside, and a Williams's hook used to snag the rope cage on top of CAMEL. The same small crane used for launch then lifts the instrument onboard.

k) References:

Osborn, T. R. and T. Siddon. "Oceanic shear measurements using the airfoil probe." Proceedings of the Third Biennial Symposium on Turbulence in Liquids. University of Missouri-Rolla, September 10-12, 1973.

Osborn, T. R. "Vertical profiling of velocity microsturcture." J. Phys. Ocean., 4:1, 109-115 (1974).

Lueck, R. G., O. Hertzman, and T. R. Osborn. "The spectral response of Thermistors." Submitted to Deep-Sea Research.

Crawford, W. R. "Turbulent energy dissipation in the Atlantic equatorial undercurrent." Ph.D. thesis, University of British Columbia (1976).

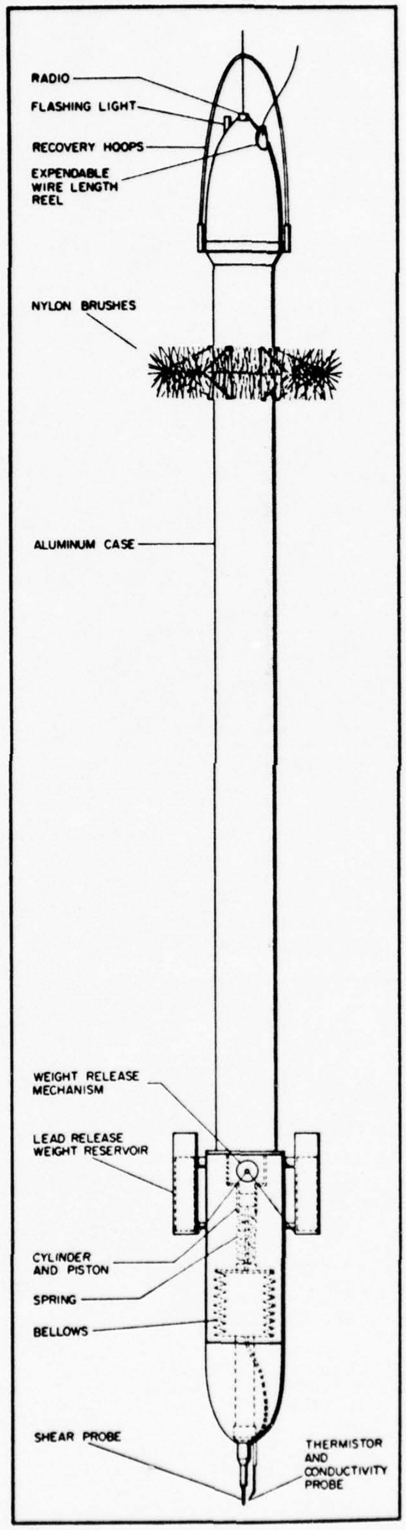

RADIO
FLASHING LIGHT
RECOVERY HOOPS
EXPENDABLE WIRE LENGTH REEL
NYLON BRUSHES
ALUMINUM CASE
WEIGHT RELEASE MECHANISM
LEAD RELEASE WEIGHT RESERVOIR
CYLINDER AND PISTON
SPRING
BELLOWS
SHEAR PROBE
THERMISTOR AND CONDUCTIVITY PROBE

Fig. A3. Camel

Description of Measuring Systems and Performance Specifications

Name of Instrument: PROTAS

By: J. H. Simpson

a) Purpose of measurement system:

PROTAS is a free fall probe which uses a pivoted neutrally buoyant vane system for measuring velocity shear. Simultaneous measurements of temperature, conductivity, pressure and orientation are also made. Resolution extends up to wave numbers of 21 rad/m, while a low wave number cut-off of $\sim$0.21 rad/m applies to the shear system.

Data is recorded twice every second and stored in digital form on a magnetic tape cassette.

The probe's fall speed is 30-40 cm/sec and the present operating depth 500 m. For a 300 m drop the cycle time $\sim$20 min.

b) *Description of primary measurement and principles of* operation:

Temperature is measured using a Fenwall GC32 thermistor housed in a hyperdermic needle to give protection from pressure.

Pressure is measured with a Bell and Howell strain gauge transducer type 4-326-L.

Conductivity is determined using a four electrode cell. The signal produced is rectified and converted to a d.c. voltage which is proportional to resistivity. Movement of the shear vane is sensed by an electrode at its tip which picks up two alternating voltages provided by pairs of fixed electrodes set at right angles to each other. In fact the vane electrode acts as the wiper of two resistive potentiometers formed by the resistive sea water path and the pair of fixed electrodes. The two signals are at different frequencies and are separated by tuned amplifiers. D.C. voltages are produced which represents the rectangular coordinates of the tip of the vane.

c) Performance specifications for sensors:

Protected thermistor response time $\sim$150 ms

1/e response length of shear vane $\sim$11.5 cm

Resolution of vane location = ±0.05 mm

Averaging length of conductivity cell $\sim$10 cm

d) Description of data acquisition system, data recorder and storage format:

Our data logger samples six channels simultaneously, averaging each time over a 300 ms period. The data is stored on a continuously running tape cassette in blocks of 12 bit b.c.d. words.

1.0 Hz, fourth order, low pass filters are incorporated in the temperature and conductivity analogue channels to minimize the problem of aliasing and to match the temperature and conductivity sensors.

e) Description of vehicle or package:

An idea of the construction and approximate dimensions may be obtained from enclosed diagram and photographs. The tube is made from HE30 aluminum alloy and in its present form is safe to a depth of 500 m.

Recovery aids consist of a luminescent orange sighting 'flag', a flashing light beacon for work in hours of darkness and an H.F. beacon.

The probe may be stored on deck.

f) Description of radio and acoustical emissions:

No acoustic emission.

Radio beacon at present operates on 27.010 mHz and transmits pulses of approximately 2 sec on/2 sec off, of signal amplitude modulated with 1 kHz tone. The range is approximately five miles, and the duration of the order ten hours on fully charged batteries.

Receiving equipment consists of 1/4-wave aerial and EC10 receiver. We would use OAR automatic D.F. equipment if available.

g) Description of data processing procedures:

One data channel at a time may be obtained in analogue form vs. time direct from tape cassette. A complete set of analogue traces may be obtained in something less than an hour.

Equipment required is tape deck and special monitor unit, both of which we have.

h) Calibration procedures and reference standards:

Pressure, temperature and conductivity calibrated in laboratory and against CTD data when available.

Shear system is calibrated on recovery and takes two minutes to complete.

i) Performance of measuring system:

1.

Parameter	Dynamic Range	Resolution
Temperature	15° C	0.005° C
Conductivity	15 mmho cm^{-1}	0.005 mmho cm^{-1}
Shear	±50 mm sec^{-1}	0.2 mm sec^{-1}
Pressure	0-500 db	0.5 db
Compass	360 degrees	1 degree

2. a) 2000 m tube may be available in time

   b) Noise on conductivity and temperature data should be reduced below digitizing interval

   c) Long term stability of conductivity may be improved

j) Description of deployment of sea operations:

The probe needs to be layed out on its support chocks near to launching point, which can be any part of ship with large working area. In case of bad weather it is necessary to be able to place the bottom half of the tube under cover to protect the electronics package when opening the tube.

A crane or davit is required to lift PROTAS from its support chocks into a vertical position clear of the ship's side and to lower it into the water. Ideally a trigger release hook should be provided (we don't have one) for releasing the probe smoothly from the cable, though a slip rope can be used. The ship's screw should be stopped until PROTAS has sunk below the surface layer.

On surfacing the ship steers up to the probe and a rope attached to the recovery frame is retrieved with a grapnel. This is then attached to the lifting gear and PROTAS is raised vertically out of the water and swung around to its support chocks.

When calibrating the shear system it is necessary to activate the electronics and hold the bottom half of the probe in the surface layer of the ocean for say twenty seconds.

Apart from the crane/winch driver, it is preferable to have three hands on deck to help maneuver the probe and if necessary a fourth man to liase with the bridge.

After every third drop the tube has to be opened and a new cassette, and (if necessary) a new battery pack, inserted.

On 300 m drops it has been found possible to maintain a consistent cycle time of one hour.

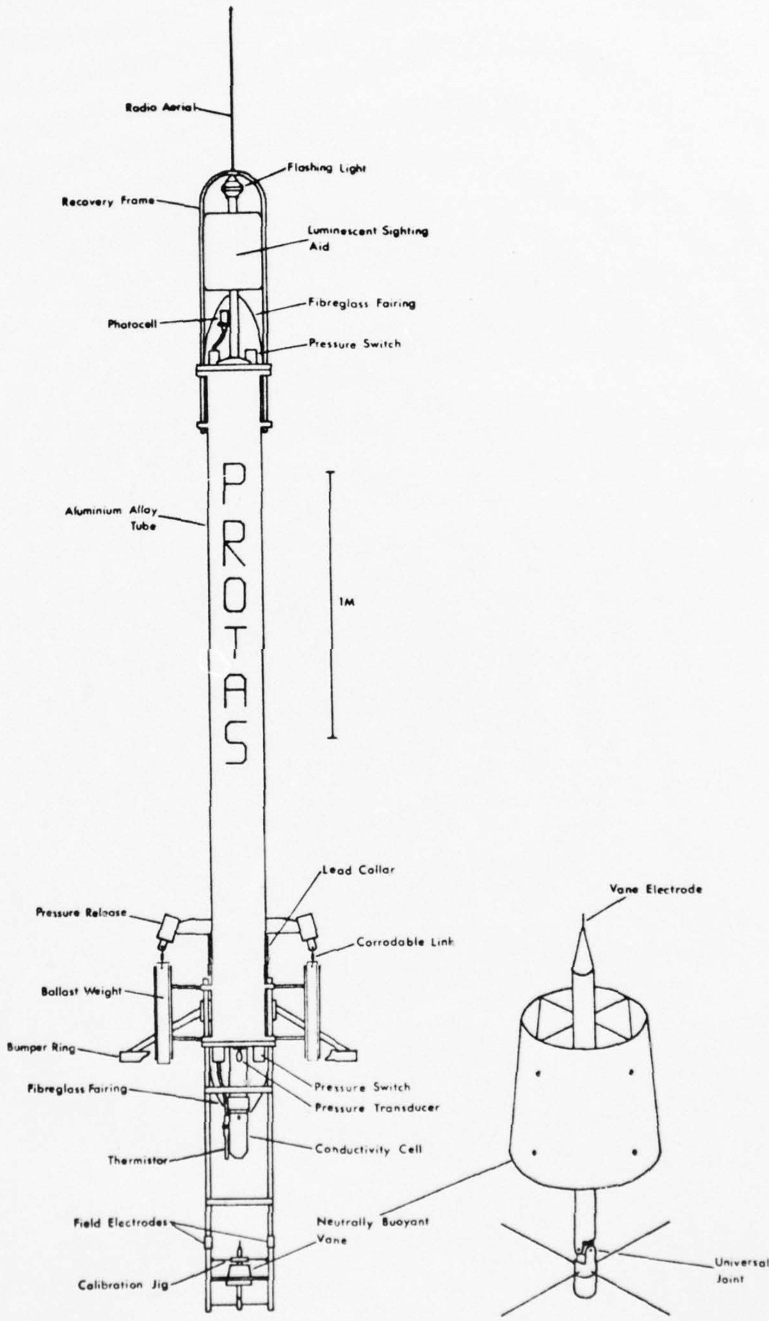


Fig. A4. PROTAS

Description of Measuring Systems and Performance Specifications

Name of Instrument: Microstructure Recorder System (MSR)

By: M. Gregg

The following is a summary of a more complete technical report that is being prepared to evaluate the system performance during the cruise.

a) Purpose of measurement system:

The purposes of the measurement system are to i) observe temperature fluctuations to the scale at which they are smoothed by molecular diffusion, ii) to measure the corresponding salinity fluctuations to scales of several centimeters, and iii) to measure horizontal temperature fluctuations to scales of about 10 centimeters. The measurements were made from a negatively buoyant free-fall tube which attained a mean fall rate of 8cm/sec by the use of large rotating wing blades. Data was taken in 250 m increments from within a few meters of the surface to 1500 m. The configuration of the system is shown in Fig. 1.

b) Description of primary measurement and princiles of operation:

Temperature is sensed with 0.02" diameter thermistors with nominal resistances of 750 kΩ at 25° C. The thermistors are driven by 30 volt batteries in series with the thermistors and 10 MΩ precision resistors. Microscale temperature fluctuations are detected using high-pass and high-gain circuits. Gross temperature was recorded from the direct thermistor output. A more stable reference temperature was also used. It consisted of a pressure protected bead thermistor as an element of a Wein bridge oscillator circuit.

Pressure was sensed with a 2250 psi vibrotron whose frequency was period counted.

High-pass and high-gain conductivity, as well as gross conductivity, were detected using a four electrode configuration in an AC bridge that was similar to a Kelvin bridge. The sensing element was a 1 mm diameter hole in the end of a Vycor tube through which sea water was sucked.

c) Performance specifications for sensors:

The actual performance characteristics obtained are complicated to describe and are frequency dependent. A full discussion of the performance, including raw data, laboratory tests, and calibrations is contained in the preliminary APL/UW technical report.

d) Description of data acquisition system, data recorder, and storage format:

Except for the Wein bridge oscillator, the data was digitized into 15 bit words for the gross data and into 16 bit words for the high-pass channels. The high-pass channels were recorded at 50 HZ, while the other data was sampled at 5 HZ. The data system used a 3200 bit $\cdot$ s^{-1} recorder made by Sea Data Corporation.

e) Recovery aids:

The instrument signals its return to the surface by a flashing light and a radio operating on citizens' band channels. Both units were made by Ocean Applied Research.

f) References:

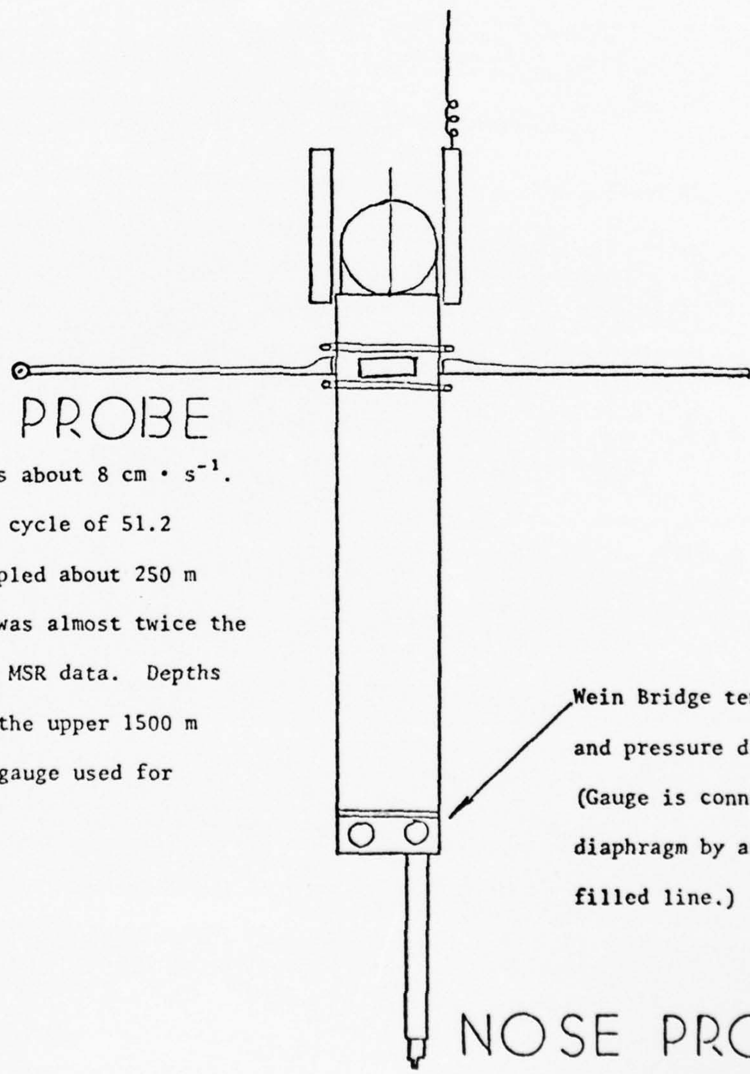
Pederson, A., 1968. "A digital depth reference." Journal of Ocean Technology, Marine Technology Society, 2(2): 28-36.

Gregg, M. and C. Cox, 1971. "Measurements of the oceanic microstructure of temperature and electrical conductivity." Deep-Sea Research, 18: 925-934.

Gregg, M. and C. Cox, 1972. "The vertical microstructure of temperature and salinity." Deep-Sea Research, 18: 355-376.

Gregg, M., C. Cox, and P. Hacker, 1973. "Vertical microstructure measurements in the Central North Pacific." Journal of Physical Oceanography, 3(4): 458-469.

The configuration of the Microstructure Recorder (MSR) as used during the Bermuda cruise was similar in principal to the descriptions in published references. However, the electrical system had been completely rebuilt with a digital data system. The mechanical system was the same as before. When taking data the locations of the sensors were as shown in the Figure 1.



The fall rate was about 8 cm · s^{-1}. With a recording cycle of 51.2 minutes this sampled about 250 m per drop. This was almost twice the span of previous MSR data. Depths were limited to the upper 1500 m by the pressure gauge used for this cruise

Fig. A5. MSR

Description of Measuring Systems and Performance Specifications

Name of Instrument: "SCIMP" - Self-Contained Imaging Micro-Profiler

By: Albert Williams

a) Purpose of measurement system:

SCIMP makes free descents to 2000 meters recording temperature, conductivity and pressure while photographing the patterns of index of refraction anomalies in the water. The descent rate is about 10 cm/sec and the digitization rate is 2.5 HZ. Six hours of data can be stored on tape within the pressure housing while 600 meters of vertical water column can be imaged on film. The purpose of the measurement is to identify mixing processes from the microstructure images and associate this with the finestructure recorded by the CTD. SCIMP dives last about 5 hours during which time the ship must remain within 3 Km of the instrument. Turn around time is about 2 hours.

b) Description of primary measurement and principles of operation:

The optical system is a photographic shadowgraph sensitive to the second derivative of index of refraction. Temperature and salinity structures at the microscale produce detectable fluctuations in index of refraction which are imaged as shadows in collimated light. W.H.O.I. manufacture.

The CTD is an internal recording version of the Neil Brown microstructure CTD. A Standard Controls strain-gauge bridge pressure transducer Model 211-35-090-02, Rosemount platinum resistance thermometer Model 171 BJ, ceramic conductivity cell, and fast response thermistor are the sensors.

c) Performance specifications for sensors:

Pressure, range: 0-4400 psi; calibration on dead weight tester: 0-3200 dbar, maximum error .8 dbar; drift with temperature excursions of 30°C: 5 dbar; resolution: .05 dbar locally free of hysteresis.

Temperature, range: 0-32°C; calibration in bath against Leeds and Northrup Standard Platinum thermometer: 5-15°C, maximum error .001°C; ice point zero recalibration: uncertainty of ice point .003°C; response time: 400 ms at flow rate of 10 cm/sec corrected to 30 ms with thermistor.

Conductivity, range: 0-64 mmho/cm; stability: .001 mmho/cm; calibration with standard seawater: salinity accuracy .010 ‰, precision .001 ‰.

d) Description of data acquisition system, data recorder and storage format:

CTD	Digitizer:	16 bit, 10 kHz, A to D converter
	Recorder:	Sea Data Digital Tape Recorder - 11×10^6 bit capacity
	Format:	16 bit record number, 16 bit pressure in units of .05 dbar, 16 bit temperature in units of .0005 °C, 16 bit conductivity in units of .001 mmho/cm
Optical	Camera:	Super 8 mm, 100 ft reel, Kodak Analyst camera
	Format:	Each picture has a circular image surrounded by 16 LED's displaying the record number from the CTD.

e) Description of vehicle or package:

Microstructure Vehicle - Autonomous platform of horizontal form 7 ft long, 1-1/2 ft wide, 2 ft high. Contains several tubes 7" diameter. Pressure vessels rated to 5000 psi, tested to 3600 psi, intended for use at 2000 meters. Weight depends on final configuration estimated 400 lbs in air. An open framework of aluminum tubing holds the aluminum pressure tubes, PVC variable buoyancy unit, weight releases, syntactic foam flotation, flag, flasher, and radio beacon together. One end of the electronics housing is removable for servicing tape and battery. Can be stored on deck but must be dry for servicing. Recovered with special latching hooks and poles.

f) Description of radio and acoustical emissions:

Acoustics: SCIMP transmits 10 ms, 20 ms, and 30 ms acoustic pulses at 5 kHz every 2 sec or more often. Forty watts is transmitted as a square envelope. Lifetime is 14 hours. The ship sends acoustic commands to SCIMP in the AMF format on channel 6 all three PRF rates. This is 40 watts acoustic power at 10 kHz, square modulated with alternating phase at 1150 HZ, in 15 ms bursts, repeated at 9, 13.5, or 21 HZ for several seconds. Special receiver and transmitter TRACS in hand.

Radio: SCIMP will have an OAR radio transmitter probably using 150 mw FSK on 26.995 mHz. Lifetime is 20 hours. No receiver in hand.

Interference: Ship noise when steaming is hard on acoustic reception. Signals of 2 sec, 5 kHz will confuse our record. We may inadvertently command another AMF receiver on channel 6 in the area of operation.

g) Description of data processing procedures:

Cassette tapes are read on cassette reader into HP 2116 computer through microcircuit interface card and dumped on 9 track tape by CARP.

CARP tape is reformatted on 9 track tape to CTD-3 format.

CTD-3 tape is processed by CTD-3 to compute salinity, potential temperature, Sigma-t, Brunt-Väisälä frequency, and dynamic height which may be plotted on a Calcomp plotter or equivalent.

If all runs smoothly, rough plots can be obtained in 1 hour or high resolution plots in 4 hours.

Analog XYY plots can be made with our equipment to 8 bit accuracy or pressure, temperature, and conductivity. Plots available in 1/2 hr.

Films can be processed in 4 hrs.

h) Calibration procedures and reference standards:

Calibration will be done in the lab against dead-weight tester, Leeds and Northrup Platinum Temperature standard, ice point, and standard seawater. Checks may be performed at sea with ice point and standard seawater.

i) Performance of measuring system:

1) Expected performance

Vertical resolution of finestructure (Rayleigh criterion) 3 cm
Image resolution of microstructure 3 mm
Vertical spectrum 3 db point 20 cm wavelength
Temperature resolution .0005 °C
Pressure resolution .05 dbar
Salinity resolution .001 ‰

2) Probable future performance

Shearmeter is planned for FAME. Resolution will be 3 mm/sec over a vertical separation of 1 meter.

j) Description of deployment or sea operations:

Crane lifts SCIMP over side. SCIMP is released. Hydrophones are streamed which restricts use of propellers. When SCIMP surfaces, the ship approaches from downwind, stops abeam and is allowed to pay off on tack to bring SCIMP into its lee. SCIMP is hooked with latching hooks, the line transferred to the crane, and lifted aboard.

k) References:

Burt, K. H., "Autoprobe: An Autonomous Observational Platform for Microstructure Studies," I.E.E.E. Conference on Engineering in the Ocean Environment, Ocean '74, Halifax, Nova Scotia, August (1974). WHOI Contribution no. 3320.

Burt, K. H., D. C. Webb, D. L. Dorson, A. J. Williams, "Telemetry Receiver and Acoustic Command System," I.E.E.E. Conference on Engineering in the Ocean Environment, Ocean '74, Halifax, Nova Scotia, August (1974).

William, A. J., III, "Salt Fingers Observed in the Mediterranean Outflow," Science, Vol. 185, 941-943, 13 September 1974.

Williams, A. J., III, "Latching Hook for Instrument Retrieval," Ocean Engng. Vol. 2, 275, Pergamon Press, 1974.

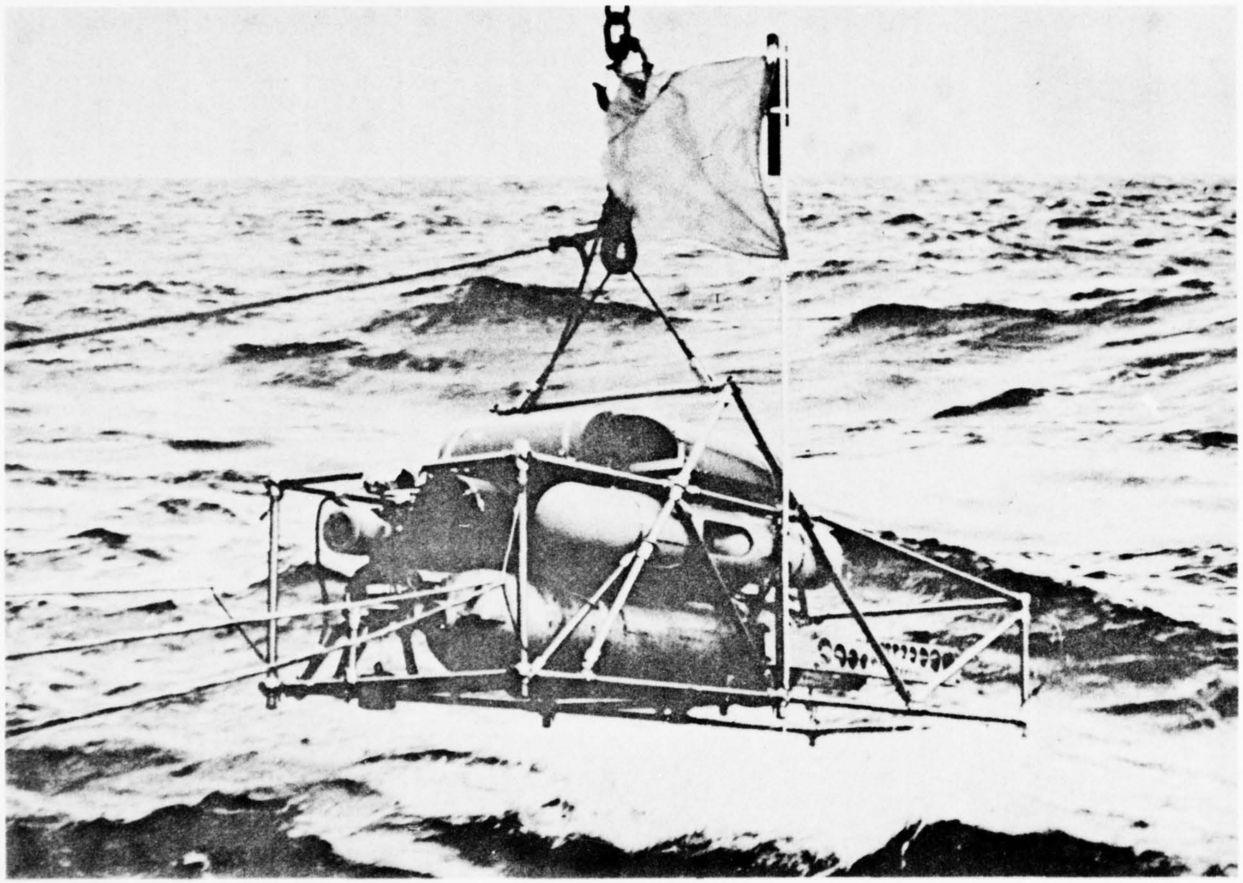


Fig. A6 - SCIMP

Description of Measuring Systems and Performance Specifications

Name of Instrument: W.H.O.I./Brown CTD Microprofiler

By: Bob Millard

a) Purpose of measurement system:

The CTD microprofiler measures pressure, temperature, and conductivity 30 times per second and telemeters digitally through a single conductor cable to a shipboard logging system. Data is logged using an audio tape recorder and/or digitally on 9-track using an H-P 2100 series computer. Stations typically require 2 hours in 5000 meters of water and the instrument is capable of measuring to a pressure of 6500 decibars. The CTD has a 17-bit resolution which resolves pressure to .1 decibars over a calibratable range 0 to +6500 decibars; temperature to .5 millidegrees over the range -2 to +32° C; and conductivity to .001 mmho/cm over a range 0 to 65 mmho/cm.

b) Description of primary measurement and principles of operation:

Pressure: Standard Controls - strain gage transducer.

Temperature: Rosemount-Platinum resistance thermometer for response to fluctuations from D.C. to 200 ms plus a thermistor bead high pass-filtered and added to Pt. thermometer response for variations from 30 to 200 ms.

Conductivity Cell: N.B.I.S. - 4 electrode direct conductivity measurement.

c) Performance specifications for sensors:

Pressure transducer Model 211-35-090, Standard Controls, Inc.

1) Range - 0 to 8850 psi (6102 dbar). This is the range over which the pressure transducer is calibrated.
2) Non-linearity and hysteresis combined - .06% of full scale.
3) Repeatability ±.05% of full scale: ±3 dbars.
4) Thermal zero drift is .0016% of full scale/°C.
5) Thermal sensitivity drift is .0023% of full scale/°C.

Platinum Resistance Temperature Sensor - Model 171BJ made by Rosemount Engineering.

1) Temperature range: 0° C to +32° C. This is the range over which the sensor is calibrated and temperature circuit linearized.

2) Resistances at 20° C: 200Ω

3) Sensitivity - .73 Ω/°C

4) Thermal sensitivity drift is .0023% of full scale/°C

Conductivity Cell - Made by Neil Brown Instrument Systems

1) Range - 0 to 65 mmho/cm

2) Accuracy - ±.003 mmho/cm

d) Description of data acquisition system, data recorder and storage format:

The data is telemetered in FSK (3-1/3 and 6-2/3 Kz) digital form in teletype format. The FSK is logged on any good quality 1/4-inch magnetic tape recorder. The deck unit outputs serial logic-levels consisting of the data and clock compatible with an H-P teletype card. The data is accumulated in the computer memory and written out on 9-track magnetic tape in blocks of 1024 words. The header and data record format is discussed in Reference 3.

e) Description of vehicle or package:

The CTD electronics is cased in a 7-inch O.D. diameter - 24-inch long cyclinder of 17-4 Ph stainless steel. The case has been pressure tested to 9000 psi. A 24-inch diameter shock absorbing frame surrounds the lower part of the cylinder to protect the sensors from banging against the side of the ship. The CTD may be left on deck.

f) Description of radio and acoustical emissions:

None

g) Description of data processing procedures:

The CTD data is edited using first difference limits which depend on the part of the water column. Normal edit limits below 200 decibars are ΔP = 1 decibar; ΔC = .03 mmho/cm; ΔT = .015° C, and 5 times these values shallower. See Reference 1 for a discussion of temperature lag correction and salinity computation. Processing requires a Hewlett-Packard 2100 series computer with 16K memory, two tape drives, calcomp plotter and teletype.

h) Calibration procedures and reference standards:

Pressure:	Laboratory calibration against a piston gauge standard, see Reference 1, page 5.
Temperature:	Leeds and Northrop platinum wire temperature probe and Guildline bridge. See Reference 1, page 3.
Conductivity:	Rosette water samples; historic θ/S relationship. See Reference 1, pages 9 and 39.

i) Performance of measuring system:

1. Expected performance:

Pressure: - ±2 decibars in 5000 decibars

Temperature: - ±.0015 degrees Celcius

Salinity: - ±.003 ppT

j) Description of deployment or sea operations:

The instrument is lowered on a single conductor electromechanical cable. The lowering rate is between 90 and 100 meters per minute. The instrument terminal velocity is between 105-110 m/min when used with a Rosette sample. Sensors are rinsed in fresh water between stations and covered with a waterproof shroud to protect against salt spray.

k) References:

Fofonoff, N. P., S. P. Hayes, and R. C. Millard, Jr. (1974). W.H.O.I./Brown CTD Microprofiler. Methods of Calibration and Data Handling, W.H.O.I. Technical Report 74-89, 66 p.

Brown, Neil L. (1974). A Precision CTD Microprofiler, Ocean 74.2, 270-278.

Tollios, C. D., G. H. Power, and D. J. Ekstrand (1971). Computer Program for Real Time Acquisition of Conductivity, Temperature, and Pressure. Technical Memorandum 4-71, W.H.O.I.

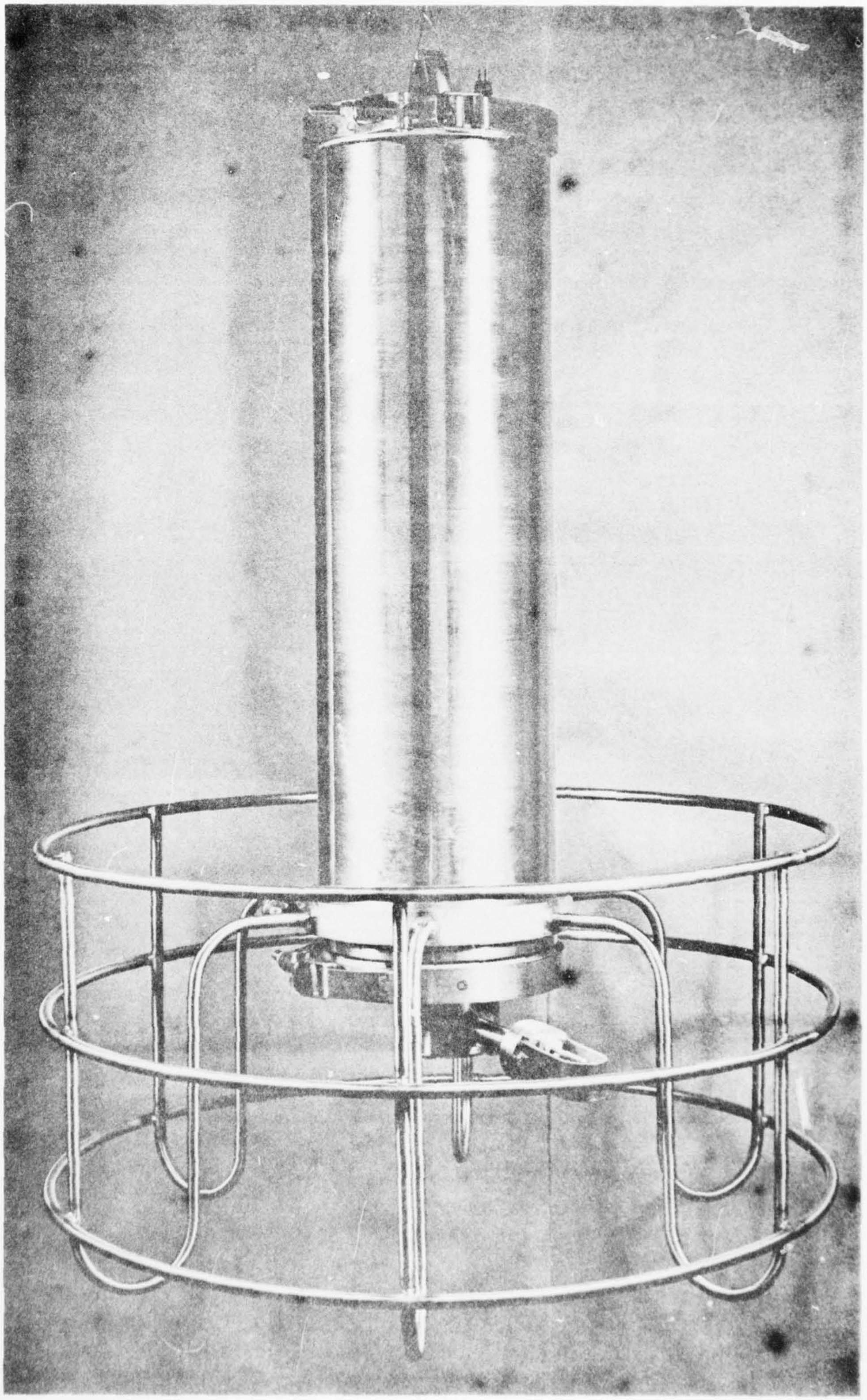


Fig. A7. BROWN CTD

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